A FLIPPED CLASSROOM TO INFORM THE DESIGN OF A GEOMETRICAL OPTICS COURSE IN PHYSICS

by

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DECLARATION

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A FLIPPED CLASSROOM TO INFORM THE DESIGN OF A GEOMETRICAL OPTICS COURSE IN PHYSICS

I declare that the above dissertation is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the dissertation to originality checking software and that it falls within the accepted requirements for originality.

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ABSTRACT

The performance of learners in the science subjects, remain low and a challenge to the Department of Basic Education. Therefore, the education system calls for science teachers to be equipped with effective teaching approaches in physical sciences in order to meet the technological needs of the country. The aim of this study was to design and implement an intervention based on flipped classroom framework, for teaching a geometrical optics course. Geometrical optics is a topic that has many technological developments, such as optical fibres, that are driving economic developments in the communication industry of any country. Flipped classroom approach is a pedagogical approach in which direct instruction is left to the individual student out of the classroom space, and the classroom space is reserved for interactive discussions under the guidance of the instructor. It is an instructional approach that is gaining attention because of its potential to improve the way science content is taught in educational institutions, by incorporating technological tools in the instructional approach. The main focus of this study was on instructional design in the following key areas: (1) the components needed to design a teaching intervention based on a flipped classroom approach framework, (ii) how these components may be used to inform the design of a geometrical optics course, and (iii) how the design intervention would impact students' performance. A Design Based Research methodological framework was used to collect quantitative data, supported by qualitative data, from five student cohorts, in a period of five years. All students were in their third-year level, registered for a Bachelor of Education degree programme. Data were collected in the first semester of each year when the course was being offered. The study findings revealed ten components of a flipped classroom instructional approach, which were derived from the analysis of data obtained during the implementation of the intervention on the five groups of student cohorts. It was also found that the intervention had a significant positive influence on students' performance in geometrical optics. What these findings implied then, is that there exist alternative possibilities of how educators may teach the science subjects in the South African context, with higher possibilities of improving performance of learners. By redesigning new instructional methods based on the flipped classroom framework, using these components as principles of designing instruction, more learners may end up performing better in the science subjects. The contribution made by the study is to theory, about instructional design knowledge, for use by other researchers in the topic of geometrical optics.

Key Words

Activity theory, course design, design-based research, factor analysis, flipped classroom approach, instruction, intervention.

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I wish to express my gratitude first and foremost to the Almighty God, for His Grace, Guidance and Protection in all the endeavours of my life. To my parents, and in memory of my mother, I thank you for your advice to embrace education as a vehicle of change in people's lives. As for my supervisor, Prof. J. Kriek, I am forever grateful to you for your unwavering support and constant drive to make sure I reach this height. To my wife and children, I thank you for your love with no bounds, shouldering a lot of challenges just to make sure I realise my potential and make this contribution to the world possible.

DEDICATION

I dedicate my dissertation work to my wife for being so loving and supportive throughout the entire doctorate program. A special feeling of gratitude to my loving parents, for I have grown to be a man out of their wisdom.

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LIST OF ACRONYMS

STEM	Science, Technology, Engineering and Mathematics
FCA	Flipped Classroom Approach
DBE	Department of Basic Education
CAPS	Curriculum and Assessment Policy Statement
SMK	Subject Matter Knowledge
B.Ed.	Bachelor of Education
BSc.	Bachelor of Science
PGCE	Post Graduate Certificate in Education
AT	Activity Theory
DBR	Design Based Research
COVID-19	Coronavirus disease of 2019
GO	Geometrical Optics
TVI	Tutored Videotape Instruction
RCOI	Revised Community of Inquiry
ARCS	Attention, Relevance, Confidence, and Satisfaction
ADDIE	Analysis, Design, Development, Implementation, and Evaluation
CHAT	Cultural-Historical Activity Theory
UbD	Understanding by Design
TIR	Total Internal Reflection
LOCE	Light and Optics Conceptual Evaluation test
SALG	Assessment of Learning Gains
ALOP	Active Learning in Optics and Photonics
UNESCO	United Nations Educational and Scientific Organization
ANCOVA	Analysis of covariance
FA	Factor Analysis
EFA	Exploratory Factor Analysis
CFA	Confirmatory Factor Analysis
PCA	Principal Components Analysis
KMO	Kaiser-Meyer-Olkin
CTE	Centre for Teaching Excellence

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

South Africa has been experiencing serious challenges in its basic education system, especially in mathematics and physical science subjects. The problem has been partly due to poor quality teaching provided by its educators (Kruss, 2009). This has impacted negatively on the quality of education in the country, causing low levels of performance in education and shortage of critical skills in areas that require scientific skills (Modisaotsile, 2012). This problem demands teacher training universities to carefully analyse how they implement their pre-service teacher preparation programmes, with particular focus on producing competent science teaching graduates that can handle the complex demands of such subjects as physics. Higher education institutions are places where various individuals are equipped with the relevant skills to meet the demands of the job market (Alharahsheh & Pius, 2021). If these individuals are poorly equipped in skills, the effects could be catastrophic for any country with an ambition to develop. Countries with economies that are well developed, such as the United States of America, European countries, Japan, China, and Russia, among others, have invested a lot in skills development of its people, especially in the Science (i.e., physics, chemistry, and biology), Mathematics and Technology (STEM) subjects (Atkinson & Mayo, 2010).

According to Kruss (2009), in the attempt to address other shortcomings of the education system in the post-apartheid school system, such as unequal financing and resourcing, the nature of school leadership and administration, the controversial change to an outcomes-based curriculum and the quality of teachers, limited attention has been given to the pivotal role played by institutions of higher learning that produce South Africa's future teachers. Attention to the quality of graduates produced by institutions of higher learning could for example possibly help minimise problems of poor performance by teachers at school level in the STEM subjects. It is therefore the responsibility of universities to train teachers with a good command of the subject matter (Ogegbo, Gaigher, & Salagaram, 2019; Kriek, & Grayson, 2009; Mji & Makgato, 2006). In third world countries where economies are still growing such as South Africa and the rest of Africa, this calls for a possible change in instructional approaches at teacher training universities to promote the use of methods that enhance deep learning instead of surface learning of course content. Such approaches include the Flipped Classroom Approach (FCA) (Ahmed, 2016). As a new educational phenomenon, FCA embodies exploitation of the internet technology to deliver content out of the classroom and awards the instructor the opportunity to address the same content at a deeper level during class time through various student-student, student-teacher, or individual interactive activities (Sezer, 2017).

Besides quality of teaching as a factor that has impacted negatively on performance of learners at school level, the complex nature of the STEM subjects must also be considered as another possible factor that tends to limit most learners at school level to perform well. A subject like physics involves topics such as geometrical optics. The topic deals with multi representations of concepts like – formulas, experiments, calculations, graphs, and conceptual explanations, all of which are supposed to be mastered at the same time (Ornek, Robinson and Haugan, 2008). Such a topic in physics cannot be merely taught using simple methods that treat content superficially if the learners at school level, or students at tertiary level are expected to competently master the subject matter. There is need for methods that promote greater conceptual understanding through application of various cognitive skills. The implication of understanding the content is found at application level within our daily lives (Mji & Makgato, 2006). Although physics is complex, geometrical optics has a lot of applications, for example, in the production and use of optical fibres in the communication industry, in the digital camera industry used in cell phones, in cameras that are used in skype technology in computers, collaborate technology of communication in online teaching where 500 students can be accommodated at the same time. Such wider applications justify the need to study geometrical optics to understand the topic conceptually at both school and tertiary levels to be able to apply the knowledge in real life situations post school and college levels.

1.2 RATIONALE OF THE STUDY

Several reasons can be provided on why designing a geometrical optics course in physics informed by a flipped classroom approach is justifiable.

1.2.1 The need to produce teachers with good command of science knowledge

The Department of Basic Education, Republic of South Africa (2016) acknowledges a poor performance in physical sciences that has been there for a long time. Not more than 40% of learners pass physical sciences with a 40% and above mark in the National Senior Certificate examination results (Department of Basic Education, Annual report, 2013). Because of poorly trained teachers in the physical sciences among other factors, this result in only a few school learners entering the university system to join the technical and science areas. Ogegbo, Gaigher, & Salagaram, (2019) argue that subject matter knowledge and teaching methods are vital to the comprehension of difficult concepts in sciences. This view is also supported by Kriek & Grayson, (2009) who also point out that poor grasp in the knowledge structure of science tend to inhibit the teaching and learning of the subject. The same can be said about teaching and learning at universities in the training of teacher candidates. Mastering subject matter knowledge requires a teaching approach that promotes conceptual understanding and application of the concepts studied. The training of competent science teachers at universities, using teaching approaches, such as FCA that enable student teachers to take ownership of their own learning is paramount. With good command of subject matter knowledge, possibly there will be a change in science subjects' performance at school level.

1.2.2 The need to acknowledge science subjects as drivers of technological and economic developments

Teachers are a critical component in the development of a workforce which is scientifically literate and capable of using that scientific knowledge in the various sectors of the economy. This workforce is born out of the school system from well performing science learners. Current studies in pedagogical strategies acknowledge flipped classroom approach (FCA) (Hamdan, McKnight, & Arfstrom, 2013), as one of the models with the potential of developing modern skills, such as critical thinking and problem solving, communication, collaboration, creativity and innovation, information literacy, media literacy, and ICT (Information, Communication, and Technology) literacy, sometimes referred to as 21^{st} skills (Scott, 2015). Exposing pre-service science teachers to this instructional strategy, brings awareness to both science teachers and learners, that science subjects are technological and economic drivers of a country like South Africa. Their exposure to FCA is an opportunity to indirectly transfer the aforementioned skills to science learners at school level.

According to Ogegbo, Gaigher, & Salagaram, (2019), physical sciences are of great importance to the technological and economic developments of South Africa. The technological needs of South Africa are addressed by innovations such as in the application of physics and the efficient teaching of physical sciences. There is a shortage of personnel with critical, analytical, problem solving and technical skills within the science industry of South Africa (Daniels, 2007; Rasool & Botha, 2011; Mateus, Allen-Ile & Iwu, 2014). Filling this gap in the science industry starts with the school system, through well trained teachers, from institutions of higher learning, using new course designs that embrace modern innovative instructional strategies. Well trained teachers have the potential to produce school learners capable of joining the science industry, thereby addressing the need for a technically skilled future workforce of South Africa. If this factor is not addressed, it could inhibit or retard the technological advancement of South Africa.

1.2.3 The need for instructional strategies that accommodate technological developments

Taking into consideration current technological developments all over the world, where the students and school learners are able to access information at any time through the internet, using smart phones, computers, and other electronic devices on the market, it is most reasonable that teaching approaches incorporate this digital environment where students are constantly interacting with each other. FCA is a teaching approach that provides a platform for the use of technology. Following the definition provided by Network Flipped Learning (2014, p 1), FCA is

> *"A pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter".*

The definition implies restructuring the class time and space where many learners sit listening to a presentation by a lecturer, replacing it with activities where students interact amongst themselves and the instructor, and are engaged in tasks designed by the lecturer, and immediate feedback is provided, rather than the lecturer simply disseminating information in front of the students. The time-space for information dissemination is dealt with at individual level out of the physical classroom environment where the student is left to prepare alone for the class time. The opportunity to incorporate technology in the teaching-learning process is at this stage of information dissemination, through video material, which can be prepared by the instructor him/herself or down loaded from the internet. Alternatively the information may be downloaded from websites that students are referred to by the instructor. The video material may be designed in ways the instructor sees fit to accomplish the objectives of the topic under study. Thus the video material may contain instructions on how to study the content, or exercises to improve understanding of the content. Students also use the environment to communicate with peers through online study group, forming a community of learners, regardless how far apart they are from each other. Students are therefore expected to attend the class session to deepen their understanding of the content they are already familiar with. The instructor ceases to be the sole owner of the knowledge, but becomes a colleague facilitating how knowledge should be acquired. In this way, development of critical thinking and creativity can be achieved. Through the introduction of knowledge students now become co-owners of the teaching-learning process, rather than passive participants as in the traditional lecture approach.

Previous studies on FCA (Kettle, 2013; Finkenberg, 2017; Asiksoy & Ozdamli, 2016) assert the importance of incorporating technology as a factor that has the potential to evoke intrinsic motivation in the student, thereby leading to greater conceptual understanding of the subject matter by the student. In a study carried out by Bates and Galloway (2012), involving a large group of students undertaking an introductory physics course, they acknowledge lecturing as an efficient way of delivering content, but not an effective way for promoting deep learning in students. Taking into consideration the merits of FCA, it becomes crucial to incorporate technology in course design such as geometrical optics, in order to facilitate social interaction through the online platform prior to class meetings, or after class meetings. Thus, in the context of training competent science teachers for addressing the South African poor science education system, FCA potentially provides pre-service teachers with greater opportunity to master subject matter knowledge through both online designed tasks or activities and in-class activities. Thus technology, for both instructor and students (the digital natives) has the potential to improve strategies for teaching and learning respectively. Because of its flexibility to be adaptable to technological developments at any level of teaching and learning, pre-service teachers may as well adopt it at the time of professional practice.

1.2.4 The need to develop science teachers' foundational knowledge of geometrical optics

The fourth reason is the need to improve conceptual understanding of geometrical optics in pre-service teachers, since the topic is also part of the high school curriculum. There is need for qualified workers in the rapidly developing industry of optics. Geometrical optics studies the behaviour of light, which is fundamental for learning optics, especially for school science learners who wish to pursue the wide range of careers in optics post their school level. An understanding of the behaviour of light by pre-service teachers will help them build in high school science learners an awareness of and interest in the wider applications of optics. Geometrical optics is studied at school level in South Africa as a subtopic under the main topic of Waves, Sound and Light. It is provided 13 hours of study in grade 11 (Department of Basic Education, 2011). The focus at this level of study is on conceptual understanding of refraction, Snell's law, critical angle, and total internal reflection. The same concepts are further studied at university level but at a greater depth, showing that this topic area has greater implications in industrial applications.

At school level, the teaching and learning is mainly focused on application exercises at all cognitive levels according to the DBE Curriculum and Assessment Policy Statement (CAPS) of the Republic of South Africa (2011). The importance of studying geometrical optics is emphasised through the *General aims of the South African Curriculum,* as pronounced in the same DBE (2011) document. Among the various aims indicated in this document, ensuring that learners acquire and apply knowledge and skills, such that the knowledge and skills have meaning to the learners' lives, is a teaching requirement expected of physical science teachers. This entails involving learners in active and critical thinking learning, rather than rote learning, but identifying and solving problems so they can make informed decisions based on critical and creative thinking. Furthermore, physical science teachers are expected to promote knowledge construction and skills formation, through strategies such as scientific inquiry, problem solving, and application of the knowledge. The CAPS document acknowledges the importance of geometrical optics and its role in scientific and technological developments in the context of South Africa (DBE, 2011). The CAPS document also provides goals that explain the need to study further geometrical optics at university level. Thus, at the time of study of this content, it was studied as a course on its own to deepen the knowledge of the pre-service teachers under training.

1.3 CONTEXT OF STUDY

When students enrol for the B.Ed. science programme, they study a wide range of courses in their first and second year. As they progress into third year, they focus on courses related to their major and minor areas of specialisation. The total number of courses studied in first year were 19 courses. During second year at university, they studied a total of 15 courses, eight during first semester and seven in the second semester. In third year, they had 13 courses in total, seven studied in the first semester and six during second semester. There were four optional courses, of which students would select two in each semester, with one of them becoming a major and the other a minor. A major in the B.Ed. program in at the institution of training, in the Department of Mathematics, Science and Technology Education, was either in mathematics, physical science, technology, or biology/life science. If a student chose one of these subject areas as a major, then the student was expected to choose a second subject as a minor. A major subject was the focus of study during the entire duration of the degree program. The choice of the major was done according to what the student wanted to do as a career choice post university study. As a requirement the student was expected to take more courses aligned to the major subject, than in the case of the minor subject. The minor subject was studied for purposes of expanding the student's range of knowledge, chosen also in consideration of the job market. As an example, a student studying a Bachelor of Education (B.Ed.) degree programme would graduate with a B.Ed. degree, in Physical Science. Such a student would be employed as a Physical Science teacher or educator. But if there are shortages of mathematics teachers within the school system, and because the student studied mathematics as a minor, the student may also be asked to teach mathematics. Thus, the major is the subject where the student has greater depth of knowledge needed to fulfil specific academic and career goals. On the other hand, the minor helps to expand the range of knowledge and field of employment. The four courses from which majors and minors were chosen were mathematics, physical science, biology, and technology. Students could make any combination of these four as a major and a minor.

Physical science is subject made up of two components - chemistry and physics which were studied during the first semester of each year in the mentioned programme. Each of these two components was allocated a double period per week on the university's main timetable. Each period was of 35 minutes duration. In addition, students were supposed to conduct two laboratory practical activities per week, one for the physics component and another for the chemistry. Because the timetable had problem of space, the practical sessions had to be arranged by the lecturer and students to be done at a time convenient to everyone.

Of the seven courses studied during the first semester in third year, one of them was a teaching practice course since the students were pre-service teachers preparing to join the teaching profession. The students had to go out of the campus for one month during that first semester and return two weeks before writing their end of semester final examinations. Geometrical optics was the physics component topic of the physical science course, studied by students during the first semester. Students taking geometrical optics were believed to be more interested in the study of physics. Under geometrical optics, students studied- the concept of light, speed of light, lenses and plane mirrors, reflection, refraction and image formation, the laws of reflection and refraction, total internal reflection, combination of lenses and optical devices. Since the geometrical optics is also studied at high school, the study of it at university is meant to provide the pre-service teachers a deeper understanding of the topic to meet the demands of the school curriculum.

1.4 STATEMENT OF THE PROBLEM

The B.Ed. in Physical Science programme means a student would graduate with a Bachelor of Education degree with a major in Physical Science. The programme is offered at the university in the School of Education, within the Faculty of Humanities. In another faculty of Agriculture and Sciences, a BSc. Physics programme is also offered by the Department of Physics. Their students study the same content in geometrical optics as those in education. These students spend the entire semester at the institution and have a fewer number of courses than their counterparts in education. Because of this, the BSc. Students tend to have a greater opportunity to master the content in geometrical optics than their counterparts in education. The BSc. Physics programme students can opt to train as teachers once they finish their studies, through the Post Graduate Certificate in Education (PGCE) programme. At the time of professional practice, they are more competent and confident in terms delivering content to the school learners.

Unlike the BSc students in the Department of Physics, the B.Ed. students specialising in physical sciences undertake their studies in an environment of multiple education and science courses, lectures, laboratory practical sessions and professional practice in education (students are out of campus for a month on teaching practice). All the activities are done in the same semester. This is a congested environment with a very dense schedule for students to develop a deep conceptual understanding in physics content (geometrical optics), especially at third year level when students are nearly completing their teaching programme. Little time is left for students to assimilate and integrate concepts and acquire autonomy, as compared to their counterparts in the BSc programme. The major drawback when pre-service teachers are trained under such circumstances is that they are likely to underperform at the time of professional practice after completion of their university studies.

On the bases of this unfavourable situation, there was need to re-design and develop the geometrical optics course to come up with a new model in terms of how the content could be taught, so that students could develop greater conceptual understanding in subject matter knowledge. Flipped classroom approach was proposed to inform the design of the course based on its merits explained earlier on (see section 1.2.1). FCA by design framework, allows some of the content supposed to be delivered in class by the instructor to be offloaded to the personal study space of the student through technology-based learning management systems. This approach lessons the burden of additional congested activities expected to be done within the short space of time available to the student. FCA is an instructional approach that promotes active learning. There are other instructional approaches that promote active learning as well, such as problem-based learning approach, inquiry-based learning approach, and computer-supported learning approach, among others. FCA was chosen for content delivery in this study because of its flexibility to accommodate the use of many different forms of technology, as well as the fact that other instructional strategies can be integrated into it to improve its effectiveness.

1.5 THE PURPOSE OF THE STUDY

The purpose of this study was to design and implement an intervention for teaching geometrical optics based on flipped classroom approach framework.

1.6 OBJECTIVES OF THE STUDY

1. To identify components of a flipped classroom approach, appropriate for designing a geometrical optics course.
2. To describe how the components work together to inform the design of a geometrical course in physics.
3. To determine the effect of the intervention on students' performance by comparing the group means of students' achievement scores.

1.7 RESEARCH QUESTIONS

The study sought to address the research problem by answering the following research questions:

1. What components of a flipped classroom approach are appropriate for designing a geometrical optics course in physics?
2. How do components of a flipped classroom approach inform the design of a geometrical optics course in physics?
3. What is the effect of the Flipped Classroom Approach (FCA) intervention on students' performance in geometrical optics in physics?

1.8 THEORETICAL FRAMEWORK OF THE STUDY

The theoretical framework that guides the entire research process in this study is the Activity Theory (AT). Kuutti (1996, p.23), defines activity theory in a broad way, "Activity Theory is a philosophical and cross-disciplinary framework for studying different forms of human practices as development processes, both individual and social levels interlinked at the same time". This definition defines how knowledge in human beings come to be, by considering that activity comes first before thinking, such that abstract notions grow out of people doing things (Hashim & Jones, 2007), and that the developmental processes of this human knowledge takes place in a social environment. It is a theory that can be used across disciplines in studies that seek to examine human activities.The importance of the role of activity in human knowledge development is also stressed by Kaptelinin, & Nardi (2012) who describe 'activity' as the basic unit of analysis, which can then be used to understand the actions of individuals (Hashim & Jone, 2007). To use AT as a framework for this study, the characteristics of 'activity' as a unit of study and source of human knowledge had to be identified. Jonassen and Rohrer-Murphy (1999, p. 62) highlighted some of these characteristics in the following statement:

> *"Activity cannot be understood or analysed outside the context in which it occurs. So, when analysing human activity, we must examine not only the kinds of activities that people engage in but also who is engaging in that activity, what their goals and intentions are, what objects or products result from the activity, the rules and norms that circumscribe that activity, and the larger community in which the activity occurs. These are all parts of the activity system".*

The value of AT as a framework of the study lies in the analysis of the subject under study through the examination of the components mentioned by Jonassen and Rohrer-Murphy above, and also identified by Hashim & Jones (2007), which are as follows:

1. Who is engaged in the activity, normally referred to as the 'subject' or the person under study in the activity system?
2. What their goals and intentions are? This is referred to as the 'object' of the activity. This forms the purpose to which members taking part in the activity direct their effort.
3. What objects or products result from the activity? This is referred to as the 'outcome' of the activity.
4. The rules and norms that subscribe the activity, normally referred to as 'rules' that govern how individuals involved in the activity work.
5. The larger community in which the activity works, normally referred to as 'community', and includes the individual workers, their colleagues and co-workers.
6. The conceptual models, tools, and equipment they use in their work, normally referred to as 'tools', sometimes referred to as 'mediating tools' since they are devices by which the action is executed.
7. The 'division of labour' which defines how actions and operations among the community members are distributed (Zurita & Nussbaum, 2007, p. 214).

Rules, community and division of labour are sometimes referred to as the socio-cultural contexts where discourse practices involving contexts such as debates, discussions, and presentations are can be examined (Foot, 2014). All the components of the activity system interact with each other

(Doubleday & Wille, 2014, p. 367) as shown in Figure 1.1. The components are located at the vertex of a triangle such that the whole system is made up of interconnected triangles. In its triad form of representation, AT provides a lens through which the interactions between the system's components, both at the level of the entire research process, and classroom level may be analysed.

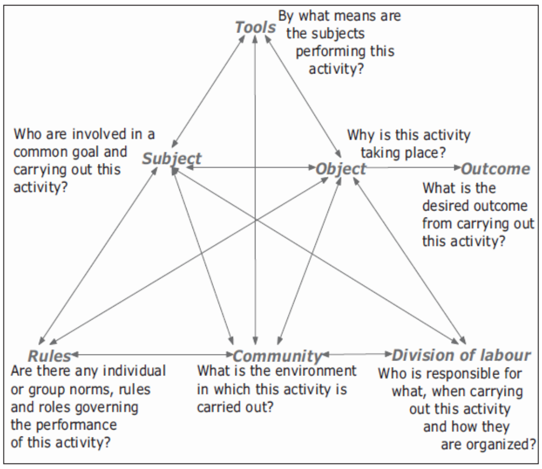


Figure 1. 1: Activity system of the AT model (Zurita & Nussbaum, 2007, p. 215)

Figure 1.2 shows the components of the activity system for examining interactions at the level of entire research process.

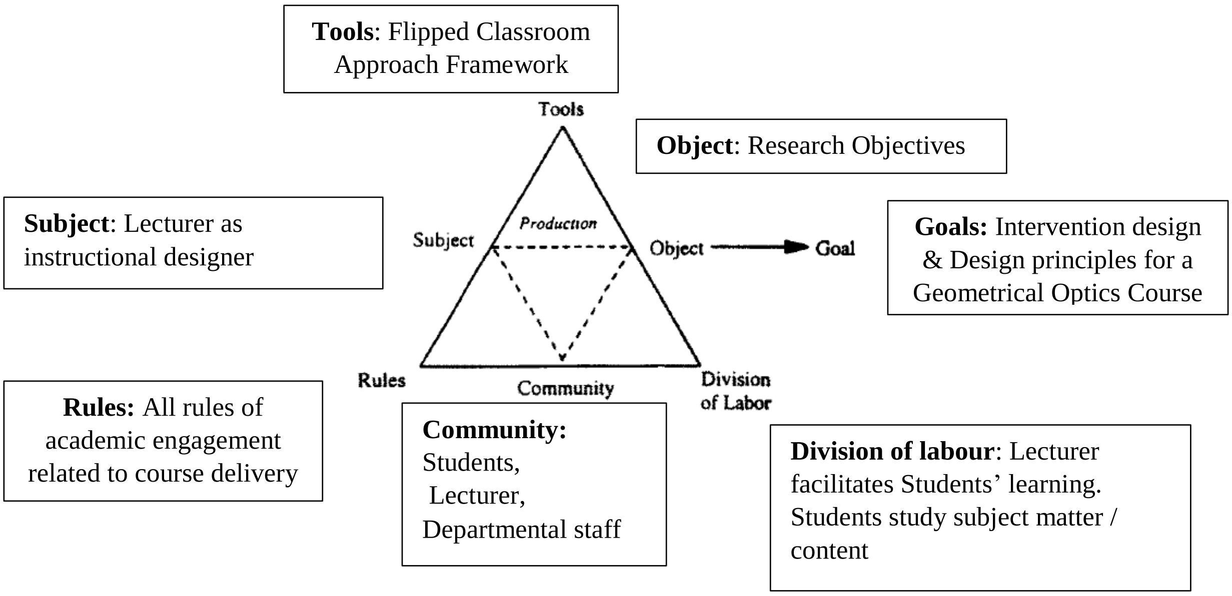


Figure 1. 2: Components of the activity system at the level of the research process

Figure 1.3 shows components of the activity triangle for examining interactions at classroom level, where students are engaged in various activities under the guidance of the lecturer.

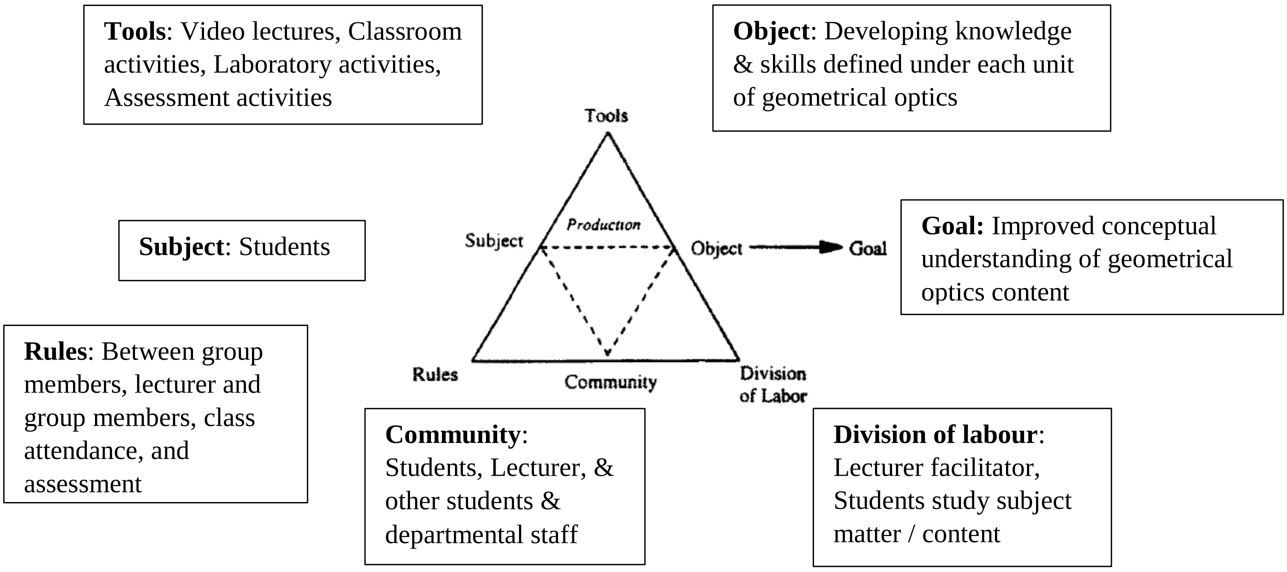


Figure 1. 3: Components of the activity system at classroom level

1.9 SIGNIFICANCE OF THE STUDY

This part of the research contains the beneficiaries of the research which are, the learning institution, the teacher, the student, the researcher, and the literature.

1.9.1 Learning Institution benefits

The study through its findings, potentially provides an opportunity for the institution to be counted among those that provide various methods of tuition to its students in the field of physics education. By implementing the recommendations of the study students are introduced to a new way of teaching and learning with greater prospects of equipping them with relevant skills for the 21st century modern society.

1.9.2 Teacher-benefits

The study also provides opportunity to schoolteachers to advance their knowledge of classroom practice by studying the design features of the final course model that resulted from this study, as well as the proposed design principles. In a study about technological pedagogical content knowledge, it is acknowledged that the current challenge for education is to discover and develop tools that enhance teaching and learning (Srisawasdi, 2012). Technology has become a powerful cognitive tool with potential benefits of transforming the way a subject is taught.

1.9.3 Student-benefits

The participant who is a teacher in the making (pre-service teacher) is exposed to an active learning strategy, a relevant tool in his/her own trade as the future classroom practitioner. As future teachers and administrators they would need to use effective instructional approaches with positive impact on student achievement and be able to creatively use valuable instructional time (Ørngreen, 2015).

In addition to equipping the pre-service teachers (students) with a powerful pedagogical skill, the students are exposed to learning experiences that incorporate technology as an instructional tool. This could enable them at the time of professional practice to integrate technology in their own teaching of physics at secondary schools. Technology brings a robust support system for learning environments (Srisawasdi, 2012). The use of technology could transform the student from being a passive spectator to an active informational architect able to procure and arrange, as well as displaying information (Evanouski, 2009). One of the advantages of technology is that it can facilitates demonstrations of how physics principles work and can be applied to the benefit of the learner (Shah, 2013). Students in addition, will be exposed and interacting with the subject matter through technology facilitated lessons, students have a first encounter with subject matter, which provides them the opportunity to be actively involved in knowledge formation.

1.9.4 Researcher–benefits

The study provides opportunity for the researcher (lecturer) to explore new ways of actively facilitating the building of new knowledge, and improvement of conceptual understanding in the student in geometrical optics. The methods of instruction employed during the training of pre-service teachers (students) preparation are likely to have an impact on the competency of our future schoolteachers as products of the training process. When they participate and evaluate their learning experience in a manner that is personally meaningful (Brame, 2014), it could possibly be used when they are teaching after their training. By facilitating FCA pedagogy the researcher (lecturer) acquires greater understanding of this active learning strategy, enabling him to train the future schoolteacher. His own method is changed through the experience of implementing the model. Other researchers may also benefit through the recommendations provided out of the study, which can be areas of further exploration.

1.9.5 Literature benefits

The study findings are a potential reference to the design of instructional approaches in geometrical optics for pre-service teachers. Thus, other researchers and instructors may find the study useful (Stemberger & Cencic, 2014), especially in a field where literature on FCA in physics is not much. The design principles that come out of the study may be adapted, adopted, or modified to suit the design of their own teaching strategies. Juuti and Lavonen (2012) acknowledge that design-based research offers new educational knowledge to act on more intelligently. The scarcity of FCA based models in physics is also highlighted by Aşıksoy & Özdamlı (2016), who have indicated that only a few studies have been done in physics at university level.

1.10 DEFINITION OF TERMS

Unlike their usual meaning from a dictionary, the following terms are defined in the context of this study for a better understanding of the study:

Components of FCA – refers to parts or elements that make up the entire instructional approach. These elements cannot be altered if the effectiveness of the instructional approach is to be maintained. They therefore represent the theory and internal logic essential for designing the instructional approach. These elements are regarded the most likely to produce the instructional approach's main effects (Merriam-Webster, n.d.).

Course – A course is a unit of study in a particular discipline, with its own instructional methods / strategies that may include different technologies or other multimedia elements that are meant to address specific learning outcomes or performance objectives (Afifi & Alamri, 2014).

Conceptual understanding - the ability to apply knowledge in other contexts other than that in which it was attained (Sands, 2014)

Context of learning - It refers to the circumstances surrounding an event, idea, a statement, term, or concept, that enables it to be used and its meaning to be fully understood. Such circumstances may include learning activities, feedback, institutional goals, rules, roles and skills of instructors, resources, among others, which need to be considered when designing for effective instruction (Afifi & Alamri, 2014).

Design-based research (DBR) - "The systematic study of designing, developing, and evaluating educational interventions (such as programs, teaching-learning strategies and materials, products and systems) as solutions for complex problems in educational practice, which also aims at advancing our knowledge about the characteristics of these interventions and the processes of designing and developing them" (Plomp 2013, 11).

Design principles - they are a set of rules that help to make design decisions, explain, and defend design rationale, as well as providing a framework to critique the designs against (Cable, 2015)

Learning - learning is a process where knowledge is actively constructed by an individual when he/she is socially involved in collaborative work with others. Contradictions within the group serve as generative forces of improvement (Wilson & Peterson, 2006).

Instructional design - This involves organization of content, sequencing of learning, assessing achievement, and the preparation of sound instructional materials so that 'teaching' can move forward (Savery, 2015).

Learning environment - these are diverse physical locations, contexts, and cultures in which students learn (Bates, 2019, p. 217). This translates to:

- Physical institutional learning environments
- Technologies used to create online learning environments
- The characteristics of the learners and their means of inter-communication.
- The goals for teaching and learning.
- The activities that support learning.
- The resources that are available, such as textbooks, technology, or learning spaces.
- The assessment strategies that will best measure and drive learning.
- The culture that infuses the learning environment (i.e., learner characteristics, content, skills, learner support, resources, and assessment)

Traditional teaching approach - a teaching associated with synchronous learning (Tularam, 2018), where class sessions are restricted to a particular place and time. The sessions are characterised by students who seat passively and expected to learn by listening, while the lecturer, teacher or instructor provides the information during the entire duration of the session. It may be that here and there a question may be asked by a student, but the teacher is in full control of the whole scenario, deciding when the questions are asked and how he/she should answer them (Schwerdt & Wuppermann, 2011).

1.11 LAYOUT OF CHAPTERS

This section gives a summary of the main chapters of the study. The study is divided into five chapters.

Chapter 2-Following the introductory discussion of this chapter one, is the literature review. In chapter 2, the theoretical tools used as the backbone to the study are discussed in detail. These are the student-centered learning theory of *constructivism*, the *activity theory* as the conceptual framework of the study, and the FCA as the tool used to transform the geometrical optics course to its new version. The discussion also centres on their relevance to the design of the flipped classroom-based model of the course as well as how they were used to develop it.

Chapter 3 presents the methodology followed in studying the problem as well as the description of the context in which the study was undertaken. The concept of design-based research, and why the study preferred this methodology, is expounded at greater length. The design principles involved in the development of the learning experiences, and why the study uses a design-based research approach are also discussed. The design process, involving several iterations of the initial course design, is discussed at length. For each of the iterations, discussions are centered on participants, data collection procedure, analysis of data, and the modifications made to each of the re-designed course models that were iterated.

Chapter 4 provides results obtained from each of the course re-designs, after their implementation and students' assessments (both quantitative and qualitative).

Chapter 5 is where the final artefact and components of FCA that inform the design of geometric optics course are presented and discussed in terms of practical and the theoretical contributions. Recommendations for further studies as well as implications for teaching and learning are presented.

1.12 SUMMARY OF CHAPTER 1

This study sought to design and implement an intervention for teaching geometrical optics based on flipped classroom approach framework. South Africa has been experiencing serious challenges in the teaching of mathematics and physical science subjects at school levels, where poor quality teaching provided by its educators has led to poor performances in the national summative examinations. This problem has created a need to relook at how educators are trained at institutions of higher learning where the teachers are trained, especially in the context of instructional design. There are possibilities of improving the status of science teaching in schools by improving how teachers are being trained. Flipped classroom approach is one of the new instructional approaches being currently studied that has the potential of overcoming the shortcomings of the traditional way of teaching, as it incorporates the new technological developments embraced by the new generation of learners known as the digital natives. Thus, the results of this study may serve various stakeholders such as university teacher educators, schoolteachers, pre-service teachers, school learners, researchers, and other educational organisations whose interest are the promotion of science education.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

2.1.1 Chapter overview

The purpose of this literature review is to provide a general overview of the flipped classroom approach as the main tool used in this curriculum design study. It is an instructional strategy that is being used to inform the re-design of a geometrical optics course in physics. The course is transformed from its original mode of direct delivery to a non-direct flipped classroom – based mode of delivery. Recently, the flipped classroom concept has become a popular approach as a new innovative way of delivering instruction in the education sector. Since the inception of the idea of marrying instructional delivery with online facilities to avoid learners being disadvantaged when they fail to attend lessons (Bergmann & Sams, 2012) many educators and researchers are experimenting with it at their institutions of learning.

With the arrival of COVID-19 pandemic, where universities and schools have been forced to close due to lock downs, virtual instructional approaches are now the mode of teaching. According to Collado-Valero et al. (2021), the authors argue that FCA is an effective alternative to the previous version of distance learning. The COVID-19 pandemic has opened the opportunity for progress of education in the context of FCA. If properly manoeuvred, the virtual meetings between students and instructors during COVID-19 pandemic, may be conducted during established teaching schedule, but adapting the face-to-face activities that were done before the pandemic to the online virtual lessons. Thus, FCA adapted to online virtual teaching has potential to be an alternative effective teaching methodology, pandemic, or no pandemic. Students would still receive recorded structured lessons on videos prior to the online virtual meetings to allow them to get acquainted with new content before class time.

The focus of this study is to explore how the flipped classroom approach as an alternative to the traditional approach of teaching, may be used in designing a geometrical course. This chapter has been divided into four major sections to understand what constitutes flipped classroom approach and how it can be used to modify course for a new course design. The four major sections are course design (see section 2.2), geometrical optics (see section 2.3), flipped classroom approach (see section 2.4), and theoretical underpinnings of the study (see section 2.5) – which is conceptual framework on which the study is anchored on.

In the first major section, course design, is further divided into five subsections that discuss the various components that constitute course design, and the influence they exert on each other and to the whole process of course design.

- The first subsection (section 2.2.1) defines the term *course design*. This is meant to provide an operational definition for a common understanding on the usage of the term throughout the entire research activity report.
- The second subsection (section 2.2.2) deals with instructional goals and objectives as an element that provides motive for students to learn and for the lecturer to design efficient and effective instruction at classroom level (Jonassen & Rohrer-Murphy, 1999).
- The third subsection (section 2.2.3) focuses on subject matter content as one of the components of *course design*. Instructional delivery must consider the nature of the content to be delivered as this has a bearing on how instruction should be conducted. As such, understanding the nature of that content helps to design appropriate instructional strategies to match the complex nature of the content. Challenges or difficulties usually faced by students in dealing with a specific type of content need to be considered during the design process.
- The fourth subsection (section 2.2.4) is about instructional approach as the key component on which the entire study is based on, using flipped classroom as the tool used to change the traditional instructional approach. This component will therefore be discussed in greater detail than the other components as it affects how instruction was conducted during course delivery.
- The fifth subsection (section 2.2.5) is about assessment and evaluation, which is also part of the tool-component in the main activity system of the entire course design study. Assessment serves to provide information or evidence on how well the content was understood by students within the framework of the defined objectives of the geometrical optics content. The evidence speaks to whether the instructional activities used to address the objectives were the appropriate ones or not.

The second major section discusses geometrical optics as subject matter in physics, its nature, and the challenges faced by students who undertake it.

The third major section discusses the flipped classroom approach (FCA) focusing on the following issues:

- What is FCA?
- Historical origins of FCA

- The use of FCA in higher education
- Models of FCA
- Components / Characteristics of FCA
- Studies on course design using FCA
- What has recent research on FCA suggested how to implement FCA
- Why use FCA to design a GO course?

The fourth major section discusses the Theoretical Framework underpinning the study.

2.2 COURSE DESIGN

2.2.1. Operational definition

Course - The word course is mostly used in higher education learning institutions. Before discussing what is meant by course design, it is necessary to provide a working definition of what is meant by the term course. The term course is widely used in higher education to indicate what a student is supposed to learn. It has no standard definition as it may be used to refer to either a programme, a curriculum, or a module, depending on regulations of who is providing the course (Youell, 2011). Most discussions in literature are centred on what is a curriculum and how it is designed. An analysis of a few of these definitions can help to come up with a working definition of what is a course. It is necessary to have a common understanding of what the term "course" refers to each time it is used in this study. The definition will help to identify the key elements that constitute a course, which in turn will help to understand what course design is about. The following four definitions provided guidance for defining the concept of a *course*, as well as identifying the elements that constitute it.

According to Kasuga (2019, p.23), a curriculum comprises of a set of desired outcomes and structured learning experiences, where the experiences are meant to achieve a set of defined outcomes. Kasuga goes further to identify the components of a curriculum as objectives, content, teaching and learning activities, and assessment methods.

Tyler (2013, p. 1) on the other hand, advises those who intent to design a curriculum to address four key questions:

- *What educational purposes should the school seek to attain?*

- *What learning experiences can be selected which are likely to be useful in attaining the objectives?*
- *How can these learning experiences be organised for effective instruction?*
- *How can we determine whether these purposes are being attained?*

Analysis of these four questions shows four key elements that make up a curriculum namely: aims or objectives, learning experiences, organisation of the learning experiences, and evaluation.

Ornstein and Hunkins (2009, p.179) also proposed the need to ask the following four questions when designing curriculum:

- *What should be done?*
- *What subject matter should be included?*
- *What instructional strategies, resources, and activities should be employed?*
- *What methods and instruments should be used to appraise the results of the curriculum?*

A closer look at all four of these questions shows four main aspects are being addressed: instructional goals, content, learning experiences and assessment and evaluation.

McKimm & Barrow (2009, p.174), presented a definition of curriculum that included the concept of a *course of study*:

> *"A curriculum defines the learning that is expected to take place during a course or a programme of study in terms of knowledge, skills and attitudes. It specifies teaching, learning and assessment methods, and indicates the learning resources required to support effective delivery. One of the primary functions of a curriculum is to provide a framework or design which enables learning to take place. A syllabus is the part of a curriculum that describes the content of a programme."*

This definition shows what constitutes a course of study, which is all what the student is supposed to learn and the learning experiences which the student undergoes. A course of study, from their description of curriculum, is fundamentally comprised of several elements. Five key elements emerge from their definition: content (knowledge, skills, and attitudes to be developed in learners), teaching, and learning methods (the means of teaching and learning), and the assessment methods meant to evaluate the effectiveness of the instructional delivery process. These four elements define what is involved in a course of study. Though the description does not explicitly talk about goals or objectives, this is defined in terms of the *learning that is expected to take place*.

In view of all four descriptions of a curriculum provided above by the different researchers, a course of study may be regarded as a composite of what the student is expected to learn, and the delivery mechanisms for achieving the specified learning targets. Its key elements can be singled out as:

- Instructional objectives and goals
- Content or subject matter
- Instructional strategies (the means of conveying knowledge to the learner, and for the learner to acquire that knowledge)
- Assessment and evaluation

Course design – Taking into consideration the elements identified in defining what is meant by a course of study, a course design refers to a detailed activity plan which proposes ways in which instruction of specified subject matter content may be presented to students and the way student learning will be affected by the approach. The following paragraphs provide explanations that help one to understand how the four elements identified in the definition of a course are essential in understanding the concept of course design. All these paragraphs attempt to explain the ways in which instruction of specified subject matter content may be presented to students and the way student learning will be affected by the approach.

2.2.2 Instructional goals and objectives

The way subject matter content is presented to students is determined by instructional goals. Instructional goals are general and provide direction for students and instructor, hence are critical to the creation and implementation of the designed course. They help in developing a comprehensive plan built to appropriate specifications and define knowledge as well as skills students must acquire when engaging with the course (Jones, Noyd & Sagendorf, 2013). Thus, course goals are the driver that provide direction to many of the activities that will take place during course implementation. Noyd (2010, p.2) argues that goals are long term objectives, hence enduring, for they deal with situations faced by students long after graduation. To stress the importance of goals in course design, Noyd points out the following characteristics of effective course goals:

"Effective course goals…

1. *Describe what students will learn and be able to do*
2. *Are actionable, visible, and measurable*
3. *Are clear and understandable to students as well as instructors*
4. *Have an appropriate level of generality*
5. *Require high levels of thinking and learning*
6. *Are developmentally appropriate*
7. *Lead to authentic / motivating tasks"*

These characteristics have a determinant effect on quality of student learning within the course structure. Instructional goals tend to guide the instructor on what content should students learn (from textbook, the internet, reference books, etc.), how should it be organised in terms of learning experiences (the teaching learning methods such as lectures, practical sessions, group discussions, self-study, field trips and learning resources such as audio-visual aids, equipment, science kits) to facilitate learning, and what assessment-evaluation methods should be used (i.e. ways of verifying whether the intended performance has been achieved) (Phillips, 2011). Instructional goals identify what should be achieved by students at the end of a course. They help in planning how the course should be delivered. According to Phillips (2011, p. 112), instructional goals may be understood to mean the following:

> *"It is the general intentions of a course of instruction without criteria of achievement. For example, 'Students will show an understanding about the tropical rainforest'. It indicates the performance expected, i.e., "***understand***", but the performance level is not stated".*

Objectives, on the other hand, are immediate intentions, achievable, measurable, and deductively follow from a learning goal. When designing a course, the instructional goals influence the instructional objective. The instructional objectives are derived from instructional goals and are more specific in dealing with fundamental knowledge and are therefore essential parts of course design. Higher order goals can only be attained once students have acquired fundamental knowledge (Huitt, 2011). Hence objectives are critical as they scaffold construction of knowledge. Instructional objectives are the immediate behavioural achievement expected in class during the discussion of a specific concept or topic. According to Phillips, (2011: p.112):

> *"Instructional objective is a statement of performance to be demonstrated by each student in a class. It is stated in a form that is measurable and observable…An example of an*

instructional objective is: 'At the end of the lesson students should be able to describe five characteristics of the tropical rainforest'"

An instructional objective therefore defines what behavioural action must be achieved during a class session on a particular topic or concept of study (e.g., the law of refraction), specifies the standard at which the performance must be achieved, and the conditions under which the action must be performed. In this study the difference between instructional objectives and instructional goals will be that instructional objectives are specific intentions to be achieved by the end of a lesson, while instructional goals will be the achievable intentions by the end of instruction of the entire module, with respect to the content under study. In an instructional objective, demonstration of learning is reflected in the action verbs that are used when stating objectives. Phillips (2011, p. 113) provides a vivid example of how an instructional objective must be framed:

"On completion of this 45-minute lesson on the tropical rainforest you should be able to:

- *Define the terms: evergreen humidity, buttress roots, and canopy.*
- *Locate the distribution of the rainforest on a world map.*
- *Explain why there is little undergrowth in a rainforest."*

An activity designed to achieve this objective would then involve students in providing definitions, use of a world map to locate rainforests, and giving reasons of the existence of undergrowth in rain forest. Bloom's taxonomy is one of the most helpful classifications in the cognitive domain that lists a person's observable and unobservable intellectual abilities such as comprehending information, organising ideas, and evaluating information and actions (Huitt, 2011).

2.2.3 Subject matter content

According to the operational definition provided of course design (see section 2.2.1), the way the content is presented to students implies reorganising the subject matter content. The nature of content (i.e., how complex it is) will determine how the instructor will plan and organise the content in terms of scope, sequence, integration, and continuity (Ornstein & Hunkins, 2017). Bain, and Siddique, (2017) provide an understandable explanation of what content organisation in a course design entails. What this means is that the concepts, factual content, and procedures that constitute the knowledge base of the course must be reorganised in a logical manner so that ideas must build upon one another, with interrelations among topics being clearly articulated. The subject matter must be organised to present learners with multiple opportunities to practice and demonstrate what they learn in variety of contexts (Bain & Siddique (2017). Such situations may be drawn from their personal experiences and real-world applications. Connecting learning in school with real-world experiences help learners to find validity in what they are involved in. In addition, students can reconstruct misconceptions as they see connections between what they are currently learning and what they have learned before, thereby facilitating internalisation of the concepts under study. This is only achievable when content is organised into meaningful patterns that facilitate the development and setting of instructional goals and objectives by teachers. Application of knowledge by students to new problems and unfamiliar contexts is only achievable when content organisation helps them understand the conditions under which knowledge application will be useful, a situation which lacks in most curricula and instructional materials. Reorganisation of the content also entails reallocation of instructional time. Thus, more time may be allocated to the study of knowledge considered most worth for in-depth learning. At the same time breadth and depth of coverage in terms of student learning outcomes must reach an appropriate balance.

2.2.4 Instructional strategies

This is about the creation of learning experiences by an instructor in order to promote knowledge construction by the learner (McKimm & Barrow, 2009). Learning experiences in practice include teaching methods such as inquiry method, discovery approach, lecture method, small group discussion, among various others which may be adopted by the instructor, and learning activities or tasks such as answering questions, solving problems, viewing videos, doing experiments, etc., which provide students with opportunities to ask questions, teachers to clarify doubts, and for students to create and apply knowledge (Phillips, 2011). What the student does, to be effective, will depend on how the learning activities are organised by the instructor. Goodyear (2015), explains reasonably how the instructor is charged with providing meaningful learning experiences in appropriate contexts in which learning can flourish:

> *"Most of the work students do—much of their learning activity—takes place without direct supervision from their teachers. Hence, teachers need to design good learning tasks and to communicate task specifications clearly to their student. Because design works indirectly—students normally interpret task specifications, rather than following them blindly (p. 33)".*

In this statement, Goodyear brings out how important the instructional component is to the achievement of the learning outcomes. This is where the design of the course is highly sensitive because there are no prescriptions that come out with the course document that are provided to the instructor. The student is not entirely under supervision of the instructor but will have to rely on what the instructor is proposing as a way forward. The instructor therefore must make decisions on what constitutes effective learning activities and in addition be an effective communicator for the student to be able to interpret what the tasks requires him / her to do while being alone. Failure to do this the outcome of the whole process of course design becomes fatal. In support to Goodyear on provision of meaningful learning experiences, McKimm and Barrow (2009, p.717) advise the instructor to look at the following:

- *How relevant are the teaching and learning methods to the content and learning outcomes?*
- *Where will the teaching and learning take place?*
- *How are practical skills going to be taught and supervised?*
- *How are students supported in independent learning and study (e.g., self-directed learning)?*
- *What resources are required and available to ensure effective teaching and learning?*
- *Does the teaching promote critical and logical thinking by the learner?*
- *What are the constraints affecting the teaching and learning process?*
- *Are the teaching and learning methods appropriate for the selected assessment methods?*

All McKimm and Barrow are pointing out through their questions is a set of essential factors that an instructor need to consider building meaningful learning experiences in which knowledge is constructed by the learner. Such factors include knowledge of teaching methods and their limitations, the physical environment in which the learning must take place, consideration of the skills such as critical thinking skills that must be developed in the learner, support measures or resources that must be put in place to facilitate the process of learning by the student, and assessment mechanisms to gauge the level of understanding of what the student assimilated. Tasks are designed for students not to see the surface feature of a problem but the fundamental principles behind it (McKimm & Barrow, 2009)

2.2.5 Assessment and evaluation

This section refers to the process of collecting data and making judgements on whether the learning outcomes have been achieved. This process helps the instructors to know whether what they are doing is effective or not, so that they can take the necessary remedial measures in the event of failure to achieve the desired purpose (Phillips, 2011). Thus, assessment methods must also cover all learning outcomes and the core content. McKimm & Barrow (2009, p. 717) suggest six points to look at when designing assessment methods:

- *Are the assessment methods which relate to the assessment of knowledge, skills, and attitudes appropriate?*
- *Do the teaching and learning methods support the assessment strategy?*
- *Are the assessment methods reliable and valid?*
- *Are the assessment methods designed so that learners can achieve the minimum performance standards set in the curriculum and is there capacity for learners to demonstrate higher standards of performance (i.e., do the assessments enable discrimination between candidates)?*
- *Are there enough assessments or are learners being over-assessed?*
- *Are the regulations governing assessment procedures and awards clear and easy to follow and are they being applied appropriately and consistently?*

Besides providing information on whether the strategies undertaken during instruction are effective, assessment and evaluation also assist the instructor by providing feedback (Howard, 2001) on whether there is alignment between goals, objectives, strategies, and assessment methods. “If a critical mass of students is not demonstrating sufficient learning, this may suggest that either learning strategies are not effective in meeting learning objectives or learning assessment methods are not effective in measuring student learning” (p. 21). Thus, learning needs to be understood in the context of a mix of teaching strategies and assessments that correspond to learning objectives of the course. If these are not aligned, learning cannot effectively take place.

2.3 GEOMETRICAL OPTICS

2.3.1 The nature of physics

Physics as a discipline demands the ability to think analytically, creatively, and independently in those who undertake to study it (Ornek, Robinson, & Haugan, 2008). One is expected to make reasoned evaluations to gain an in-depth knowledge of physics concepts, and to develop confidence and skills needed in conducting scientific investigations. It demands an awareness of its interaction between theory and practice in those studying it. An example of its level of demand is reflected in the language involved in its study which involves a lot of symbols, analysis, and mathematical logic and precision. Words have precise scientific meanings, and must be learned promptly and accurately, as they build meaning one layer upon the other. Unless one knows exactly what the previous term or concept means, it is difficult to know what the next one is talking about as one word leads to the understanding of the other. This same principle applies in calculations. Any minor error in a calculation can affect the entire procedure leading to a wrong answer. Thus, as pointed out by Bueche and Hecht (1997), doing things the right way is very important in physics, for both concepts and calculations.

In addition to the above expectations, physics poses to learners, it uses different representations such as graphs, experiments, laws, and principles, formulas and calculations, and conceptual explanations at the same time. (Tural, 2015; Ornek, Robinson, & Haugan, 2008). Physics is difficult for most students. This is a fact explained by Ebora (2016, p. 37):

> *"Physics as a discipline requires learners to employ a variety of methods of understanding and to translate from one to the other--words, tables of numbers, graphs, equations, diagrams, maps. Physics requires the ability to use algebra and geometry and to go from the specific to the general and back. This makes learning physics particularly demanding for many students".*

2.3.2 Optics

Optics is a branch of physics which studies how visible light and other electromagnetic waves interact with matter (Pedrotti, 2008). The study is facilitated by dividing the main branch into two other minor branches known as Physical optics and Geometrical optics. Physical optics is further divided into two other branches namely Wave optics and Quantum optics. These branches of optics study the behaviour of light under specific conditions. A flow diagram showing how the four branches are organised is shown in Figure 2.1.

2.3.3 Physical optics: the wave and particle models of light

Physical optics is further divided into wave optics and quantum optics, while geometrical optics remains as it is. The wave optics studies the interaction of light with objects whose dimensions are comparable to the wavelength of light. Wave optics uses the wave model to represent the behaviour of light at such microscopic level comparable to the wavelength of light. At microscopic level, light exhibits such characteristics as constructive and destructive interference as well as diffraction. These phenomena are known as wave characteristics. Thus, wave optics deals with interference, diffraction and polarisation, and the light is said to be propagated as wave motion. Wave optics is also known as wave model. Quantum optics still under physical optics, is used to explain the interaction of light with individual atoms. It assumes that light is a stream of particles called photon-which is important in the explanation of the origins of line spectra, photoelectric effect, Compton effect, radian pressure and laser effects. Quantum optics is also known as the quantum model and is used to explain phenomena associated with emissions and absorption of light. The wave model and the quantum model are both models of light. However, each model is used to explain the behaviour of light where the other model fails to do so. Because two models are used to explain the same phenomenon of light, though under different circumstances, light is regarded as having a dual nature, (normally referred to as the wave-particle dual nature of light). These first two models discussed here are used to study the behaviour of light at microscopic level.

2.3.4 Geometrical optics: the ray model of light

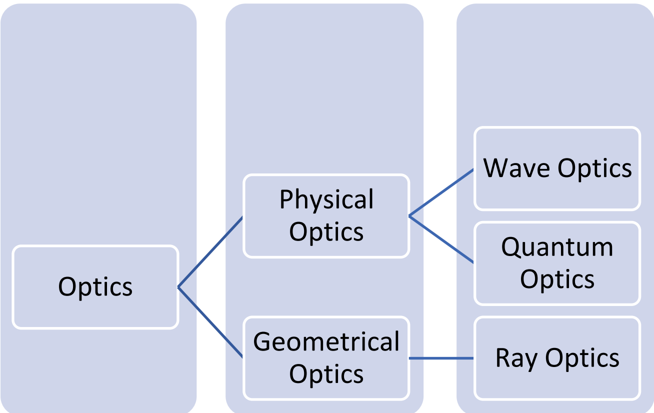


Figure 2. 1: Optical branches under which behaviour of light is studied.

Geometrical optics is a graphics-dense subject replete with diagrams of straight lines, depicting direction of flow of light energy from sources, or traversing across boundaries such as from air into water, or glass (Pea, Sipusic & Allen, 1990). Light is treated as travelling in straight lines called rays. This ray model is a tool used to help describe the behaviour of light as it interacts with matter at macroscopic level. It is used to describe behaviour of light when it interacts with an object that is several times as large as the light's wavelength. The wave characteristics mentioned earlier on under wave optics are not exhibited under this situation. This part of optics is referred to as "geometric optics" and this study's focus is on such situations. Comparing what the wave model and the ray model describe, geometrical optics becomes the limiting case of wave optics, when size of obstacle in the path of light becomes much larger as compared to wavelength of light. Thus, the wave nature of light is ignored, and rectilinear propagation of light is considered. Rectilinear propagation of light is modelled as the ray model or is sometimes referred to as the law of rectilinear propagation of light. This law states - the rays of light in an isotropic medium are straight lines, where the ray is understood to be the path which light pursues. Within this understanding, rays are not material objects made but hypothetical representations invented to simplify how light behaves or is propagated through space in a simpler way. In most cases physics uses models to make the phenomenon being studied understandable. A model in science is usually a representation of the phenomenon being studied but in a simplified version than what it is (Frigg & Nguyen, 2017; Uchinokura, 2018).

2.3.5 Alternative conceptions

Alternative conceptions are a term that has been widely discussed in literature under different labels, namely: misconceptions, preconceptions, alternative frameworks, naïve conceptions, children's science, common sense concepts, spontaneous knowledge, wrong opinions, pre-cognitions, and common notion concepts (Blizak, Chafiqi & Kendil, 2009; Kaltakci, 2012; Taşlidere & Eryilmaz, 2015; Abimbola, & Baba, 1996; Ozcan, Yildirim & Ozgur, 2012). The central idea behind each of these different terminologies is that it refers to beliefs that do not coincide with the acceptable scientific idea presented in the classroom by the instructor, lecturer, or teacher. There is conflict between explanations given by students and the scientific opinion. The scientific view is that alternative conceptions, misconceptions, or any of these terms represent ideas that are unscientifically acceptable, or knowledge contrary to the scientific facts (Kose, 2008; Ozcan, Yildirim & Ozgur, 2012). Despite the common idea that binds all these terms to the same meaning, researchers prefer to choose one term over another, based on certain reasons they find justifiable for doing so. For example, Taşlidere and Eryilmaz (2015) preferred to use, misconceptions because to them it refers to an idea that is in direct conflict with scientific ideas. Abimbola and Baba (1996) considered that when the term misconception is used, the idea behind the use of the term is a concept clearly in conflict with scientific conceptions and is therefore wrong, while the use of the term alternative conception would appropriately describe "an idea which is neither clearly conflicting nor clearly compatible with scientific conceptions, but which has its own value and is therefore not necessarily wrong" (p. 15). In view of Thijs and Van Den Berg (1995), alternative conceptions are a term that must be used when ideas in the student have robustness and persistence across ages and levels of schooling and may have resulted from previous schooling because of incorrect teaching or incorrectly assimilated formal instruction. Meaning to say the ideas have been used and found useful to some extent across different ages and levels of schooling. However, they did not consider preconception to mean the same thing as alternative conceptions. They regarded preconception to be "a conception which has been formed without exposure to formal instruction in school, also called: intuitive or pre-instructional conception, spontaneous knowledge, children's science, folk knowledge" (p. 318). They viewed it as the idea held by students before a topic is taught, and so are part of alternative conceptions. In this study, the term alternative conceptions will be used on the same basis of reasons provided by Abimbola and Baba (1996) as well as those of Thijs and Van Den Berg (1995).

Some of the reasons leading to alternative conceptions may include: an attempt by a student to reinterpret new knowledge after a prior attempt to integrate new information with previously held information (Blizak, Chafiqi & Kendil, 2009), information a student may previously hold but with insufficient cognitive enhancement (behavioural enhancement strategies used by students such as language learning), poor instructional strategies on the part of an instructor (Ozcan, Yildirim, & Ozgur, 2012), flawed understanding of concepts on the part of a student due to level of difficulty (Lucariello & Naff, 2013), opinions and intuitions formed around physical phenomena which are a result of prior learning at school, or due to interaction with the physical and social world (Blizak, Chafiqi & Kendil, 2009).

According to Kaltackci (2012), alternative conceptions have a common feature that they are strongly held and are coherent structures. They cannot easily be changed by mere use of traditional methods. Rather they need special attention with a focus to develop scientific understanding. Blizak, Chafiqi and Kendil, (2009) provided a summary of these features as; frequently similar to each other for students in different countries and region, strongly held and difficult to change through regular instruction, can be caused by culture, religion, and language, scientific explanations and alternative conceptions may be used together in interpreting scientific phenomena, and lastly, they may also develop after teaching.

Lucariello and Naff, (2013) explain how alternative conceptions tend to impede learning. Firstly, students do not even realise that the knowledge they have is wrong and can be very entrenched in their thinking. New experiences are interpreted using the erroneous understandings hence new information cannot be correctly grasped. Learning on the other hand entails radically reorganising student knowledge, misconceptions tend to resist the reorganisation of knowledge. It therefore becomes a challenge to instructors to bring about significant conceptual change in student knowledge. Traditional or ordinary strategies such as lectures, labs, discovery learning, or simply reading texts, are not effective for overcoming student alternative conceptions (Lucariello & Naff, 2013). Taşlidere and Eryilmaz (2015), considering the challenges faced by instructors, commented alternative conceptions as "the cognitive structures to change, they create a barrier to knowledge restructuring and affect learners' scientific understanding" (p. 270).

In view of their ability to impede learning, correct identification of student alternative conceptions is necessary (Kaltakci, 2012) for planning instructional strategies. The following section describes the acceptable scientific conceptions taken from the official course content document, together with the unacceptable student conceptions from literature, as well as a proposition of the possible instructional strategies that may be used address these alternative conceptions.

2.3.6 The B.Ed. curriculum content in geometrical optics

The key concepts about geometrical optics that student was expected to correctly conceptualise from the official curriculum document (see Appendix A) on completion of the course were namely: *concept of light, speed of light, lenses, and plain mirrors, three principal refracted rays and image formation, reflection of light, total internal reflection, Snell's law, ray diagram for lenses, and combination of lenses and optical devices.* However, the official curriculum does not provide details on what should be emphasised as important scientific conceptions under each of the key concepts from the official curriculum document.

The following list adopted from Kaltakci-Gurel, Eryilmaz, and McDermott (2016, p. 4) was used by the instructor as areas that needed emphasis to minimise students' alternative conceptions in geometrical optics:

1. An object is a collection of object points, and an image is a collection of image points

2. When the light rays themselves converge to an image point it is called a real image. When the light rays do not converge to an image point, but the extensions of reflected or refracted rays converge to an image point, it is called a virtual image
3. Each point on a real image emits (or reflects) an infinite number of rays in all directions. Each point on a virtual image appears to emit (or reflect) an infinite number of rays in all directions
4. When light strikes a mirror surface, the rule of reflection holds true
5. When light meets with a lens, the rule of refraction holds true
6. Light diverging from a real image point must enter an observer's eye for the image to be observed
7. Light diverging from a virtual image point must enter an observer's eye for the virtual image to be simultaneously formed and observed
8. The position of an image depends only on the position of the object relative to the mirror and independent of the observer's position
9. The number of images formed and observed in hinged plane mirrors (two mirrors case) depends on the angle between the mirrors, the position of the object located, and the position of the observer
10. A screen is a convenience for observation of real image points in space (i.e., aerial image) and there is a particular image position for a sharp image of an object to be observed on a screen
11. The light ray is a representational tool to show the direction of light propagation.
12. The special rays serve as an algorithm to locate the position of an image. Any combination of two of these is sufficient to locate the position of an image. However special rays are sufficient but not necessary to form an image point.

2.3.7 Students' alternative conceptions on geometrical optics

This section discusses students' alternative conceptions in geometrical optics as highlighted from literature (Kaltakci-Gurel, Eryilmaz, & McDermott, 2016, pp. 11-23; Arons, 1997; Goldberg & McDermott, 1986; Andreou, & Raftopoulos, 2011).

Propagation of light – scientific conceptions view light as a physical entity that propagates in space from one point to another. It is an entity that exists between and is that which links the object and the eye. However, students' conceptions contradicting these scientific views tend identify light with its source (Andreou & Raftopoulos, 2011). Their understanding is that it is a localised entity which does not move at all but static in space in regions of illumination around the source. This erroneous understanding is reflected in diagrammatic depictions used by student to represent light which are simply short straight lines around the source without arrows that show light is an entity that has direction of travel, but instead as just a region of brightness of the light. Where lines are drawn between the eye and object, they are meant to stand for line of vision. On the other hand, some students interpret the brightness of a light source through rays of light as actual constituents of the light produced, such that the greater the brightness in a locality the greater the number of rays emanating from the source. Thus, brightness becomes a measure of the number of rays emitted.

The concept of a light ray - the ray of light is described by the ray model of light which defines it as a mere mathematical construct and a tool necessary to describe the macroscopic behaviour of light using rules of geometry. It only serves to represent the direction in which light flux expands in space. According to the scientific conception, light rays are a geometrical representation of the behaviour of light under specified conditions. A ray is an imaginary directed line drawn perpendicular to wavefronts. Its direction at any point in space shows the direction in which the wave's energy is travelling at that place. It is therefore a theoretical entity that enables us to explain the rectilinear propagation of light and image formation (Thibaut et al, 2018). It is used by the scientific community as a geometrical tool meant to improve our understanding of optical phenomena. However, students' conceptions of a light ray tend to be incompatible with these accepted scientific ideas. They think of it as a real, physically existing entity, and at times, to be of a material nature. Light is regarded as an aggregation of discrete rays.

Role of the screen in image formation - the purpose of a screen in image formation is to reflect light rays to the observer's eye so that the image formed may be seen from different places. There is a particular position from an optical device where a screen must be placed to observe an image of an object situated at a specific distance from the optical device. A real image will exist at a point where light emanating from a point on an object, is transmitted or reflected by a lens or mirror respectively, such that it passes through that common point. However, students tend to have alternative conceptions in terms of the role played by the screen with respect to the formation of a real image. Their understanding is that a real image cannot exist in space in the absence of a screen. They also believe that from the point where the screen clearly picks up the real image, if the screen is moved further away from this point, or closer to the optical device (lens or mirror), the image of the object would still be seen on the screen but with a different size or orientation.

Knowledge transfer in mirrors / lenses – the acceptable science ideas on image formation in a convex mirror and diverging lens requires students to understand that, if an object is placed at the focal point, a virtual image of the object is formed between the focal point and the mirror or the lens. For a convex mirror this image is formed at the back of the mirror between the mirror itself and its focal point, regardless of where the object is located. For the diverging lens the image is on the same side with the object but still between the focal point and the lens. However, students tend to incorrectly transfer knowledge in one context to another context resulting in alternative conceptions. When an object is placed at the focal point in a concave mirror or convex lens, no image would be formed. Students take this understanding to be also applicable to convex mirrors and diverging lenses. They generalise that no image is formed/seen of an object at the focal point in a convex mirror/diverging lens /lens. This is not true as has been explained at the beginning of this paragraph. As such this becomes an alternative conception to be dealt with by the instructor during instruction.

Emission of light by objects – scientifically there are two types of sources of light- luminous bodies which are those that produce light by themselves, and non-luminous bodies which are those that when light falls on them, they reflect it in other directions. From a scientific perspective, the luminous or non-luminous body or object is a collection of points, and all object points emit light equally in all directions isotropically. For those objects that reflect light that falls on them, each of the object points emit an infinity number of rays when light falls on the object. Any two or three rays may be selected from the infinity number of rays to locate an image of an object point, provided these selected rays are able to converge after they pass through an optical device being used in image formation of the object. The usual practice in the study of optics is to use three special rays. Special rays (at least two of them) are sufficient but not necessary to locate the position of the image. These rays are just convenient for locating image positions because their rules are simple. They are selected from an infinity number of rays emanating from an object point. However, students tend to think special rays are necessary to form/see an image, not realising that any other set of rays from the same object point can also be used for image formation. An example where students fail to use this knowledge is the case where an obstacle is placed between an object and a plane mirror. According to students, only the image corresponding to the uncovered portion of the mirror would be seen. This conception arises due to ray tracing that only involves rays drawn perpendicular from each object-point to the surface of the mirror. Students believe in the holistic image projection i.e., the image is projected on a screen or a mirror and thus perceived holistically. They do not have an understanding that the whole image is formed out of small images. According to students, if rays from object-point meet the mirror surface, the image of an object-point was thought to be formed / seen on the mirror. Students fail to realise that each object-point emits infinity number of rays in all directions and can be used to trace the image of all object-points-hence full image is still observable. In some cases, students tend to use the same diagrams to explain image formation of different optical phenomena. An example is when students use same diagrams to explain, firstly cases such as that of image formation when an obstacle is placed between object and plane mirror, and secondly, cases when an object lies outside the border of a plane mirror. Their conception is that only the images of the objects within the borders of the plane mirror are formed / seen. An image of an object lying outside the borders of a mirror is not formed or seen since the object is not in line with the mirror. In their faulty conceptions, students only consider rays that strike the mirror perpendicularly, to be the only responsible rays for image formation. Similar alternative conceptions occur when students use lenses under image formation by refraction. Their understanding is that when different parts of a lens are covered with cardboard, no complete image would be formed on the screen. They fail to understand that any portion of the lens would be sufficient to form a complete image if light from the object points can reach the lens. Covering some part of the lens only results in a dimmer image. Students therefore fail to use other diagrams that make use of rays emitted in other directions by the same object point to form an image in the mirror or lens.

Visual perception – the eye plays an important role in the process of image formation as a detecting device. The eye has a lens that collects diverging rays from an object to the retina. The retina on the other hand has receptors that transmit the information to the brain, which in turn make up the necessary interpretations of what is seen. The observer therefore constitutes an integral part of the optical system. Image formed by mirrors and lenses are of two types: real and virtual. A real image is said to be formed when light rays converge to an image point, while a virtual image is said to be formed when light rays do not converge to an image point, but their extensions converge to an image point. Unlike real images, virtual images are formed only within the observer’s eye, and not in air. In case of spherical mirrors, an observer can only see an image of an object when light rays from the object reflect back into the observer’s eye. An observer can also see the image of his / her own eye but only when the eye is placed along the normal line to the surface of the mirror (assuming the size of the eyes and the distance between the eyes are small). In a lens, the light rays from an object refract and pass to the other side of the lens. So, there is no way for someone to directly to see themselves from a lens (ignoring the reflections), because the light rays cannot reach back to the observer’s eye. The alternative conceptions related to the observation of real and virtual images are as follows: (i) students explain visual processes as a direct act of the observer on the physical object. Meaning to say light rays leave the observer to the object and an object simply must be illuminated to be seen. Thus, vision is simply assumed to come naturally with the presence of the eye. (ii) Students fail to realise that when dealing with virtual images, an observer is part of an optical system. They consider image formation to be a separate event from image observation - meaning that image formation has no relation to the observer's presence. (iii) In the case of spherical mirrors and lenses, students' lack of scientific understanding is that only the images formed on the same side as an observer can be seen, implying that only real images for mirrors, and only virtual images for the lenses would be seen.

Image in a plane mirror – a person observing his or her own image in a vertical plane mirror hanged on a wall can see his / her full image provided the mirror size is at least half of the person's height. The size of the image formed in a plane mirror depends on the size or the orientation of the plane mirror on the wall. However, students have the faulty conception (Kaltakci-Gurel, Eryilmaz, & McDermott, 2016) that the size of the image of an object in a plane mirror is affected by the distance between the object and the mirror, and by the distance of the observer to the mirror. Thus, to the student, changing the distance between mirror and observer affects the extent to which the image seen in the plane mirror. One can see more of himself / herself when he / she moves away from the mirror as more of the body parts fit into the mirror. Moving closer to the mirror may also cause the field view of the person to increase, thereby allowing the person to see more of their body.

In summary, students' alternative conceptions in geometrical optics, as highlighted in the previous section seem to be centered on their failure to fully understand four key concepts that deal with propagation of light in ray optics, namely: (i) the ray of light, (ii) the emission of radiation from light sources, (iii) the re-emission of radiation from non-luminous bodies, and (iv) the process of visual perception (Andreou & Raftopoulos, 2011). The ray of light is described by the ray model of light which defines it as a mere mathematical construct and a tool necessary to describe the macroscopic behaviour of light using rules of geometry. It only serves to represent the direction in which light flux expands in space. The emission of radiation is the model that considers radiation to be emitted from each point of the surface of a source to all directions. It enables light phenomena such as: penumbra around shadows, the pinhole images and the images seen through mirrors and lenses to be explained. The re-emission of radiation from non-luminous bodies is the model that helps to explain the visual perception of non-luminous bodies, as being based on the idea that light is reflected on and therefore re-emitted by the surfaces of all bodies. In this way non- luminous bodies act as sources of secondary luminous radiation and stimulate the eye. This model helps to understand image formation by reflection of light using mirrors and image formation by refraction of light using lenses. The fourth factor termed "the process of visual perception" describes visual perception of bodies to be a result of the light from an observed object being able to reach the ocular system. According to Andreou & Raftopoulos (2011), this forth factor demonstrates the role of psychology in explaining visual perception - meaning once light reaches the eye system, interpretations take place in the brain, giving meaning to what is being observed by the eye. This model shows that the eye is part of the optical system in the process of image formation, and hence should not be ignored during instruction. Objects and images can only be seen provided light from these has entered the eye. The position of the eye should be part of the study in image formation.

2.3.8 Teaching strategies to address alternative conceptions in geometrical optics

In a study by Galili and Hazan (2000), where the authors explored high school and college students' knowledge of light, vision, among other related topics, before and after instruction, the authors pointed out that knowledge of students' alternative conceptions by instructors or teachers is fundamental to the design of curricula and teaching tools. Students have pre-conceived notions of concepts they are taught in optics as has been elaborated in the previous section, and these can only be eliminated through well designed teaching strategies. The alternative conceptions discussed earlier on have been noted to be centred on four models: (i) the ray of light, (ii) the emission of radiation from light sources, (iii) the re-emission of radiation from non-luminous bodies and, (iv) the process of visual perception (Andreou & Raftopoulos, 2011). Effective instruction should then concentrate on building a conceptual understanding of these four models or concepts in the student and the ability to effectively apply them to various physics contexts unfamiliar to the student.

Instructional strategies related to the ray model of light

The ray model is considered to be a powerful tool when it comes to explaining optical phenomena (Kaltakci-Gurel, Eryilmaz & McDermott, 2016). It is through the ray concept model that the concept of rectilinear propagation of light can be understood by students. It enables the use of single light ray diagrams which are mainly used in all phenomena related to reflection and refraction of light (Andreou & Raftopoulos, 2011). The authors give a good example of how students can be made to explain the application of the ray concept. Knowledge of the ray concept by students can be developed through conceptual questions that demand them to explain the lateral inversion of images in plane mirror. Lateral inversion is explained because of rectilinear propagation of light and its reflection on the mirror and is not supposed to be attributed to the optical device.

Another instructional strategy suggested by these authors is to devote more time to solving problems involving lines with arrows depicting direction of travel of light. During this stage of instruction, the abstract nature of the ray concept is emphasised, and why it is used as a hypothetical concept. Students are expected to develop awareness of the fact that the ray concept or model of light is a geometrical model of light, which is less demanding to understand when it comes to studying optical phenomena than the other two models of light: the wave and quantum models of light. Thus, it helps students understand most optical phenomena since the model can adequately explain most phenomena in their everyday life. Goldberg and McDermott (1987) suggested constantly reminding students that the ray model only serves to simplify our understanding of how light behaves. It does not reflect the real nature of light in terms of its quantum nature and wave nature. Thus, a ray should be understood by students not as a material object but a hypothetical representation.

Instructional strategies related to the emission and re-emission of radiation from light sources

One important methodological advantage identified by Andreou and Raftopoulos (2011) with respect to the emission and re-emission models of light is that these models allow students to treat any extended source of light as an assembly of point sources. This allows students to be able to make use of more than one ray as strategy for solving problems involving ray diagrams, during the study of image formation by reflection and refraction in mirrors and lenses. Students can draw geometrical images in cases where light passes through an aperture, lens or is reflected from a mirror, using different ray combinations. This action can only be based on the understanding that a single object point can emit an infinity number of rays in all directions in relation to the point emitting the light. Thus, the use of special rays in ray tracing strategies is meant to simplify the process of predicting image position since these rays follow simple rules when they encounter an optical device (mirror or lens). Emphasis is therefore given to simplification and not necessity. Goldberg and McDermott (1987) stress the importance of pointing out to students, right at the beginning of instructional activities involving the use of special rays, that special rays are only one among an infinity number of rays. Students may then be given tasks in which they draw many rays in addition to special rays (Andreou & Raftopoulos, 2011). These rays must be drawn diverging from every object point. The idea behind this instructional strategy is to emphasise the fact that any ray diverging from the object point and can hit the optical device (mirror / lens) will pass through the image point. Several trials may be done before special rays may be used to simplify the drawings. Thus, students may come to understand why special rays are useful due to the simple rules of tracing their paths.

Instructional strategies related to visual perception

Alternative conceptions related to visual perception are about how students interpret what they observe as an image, whether it is real or not, and how it can be detected. This suggests use of instructional strategies in which students are actively involved in the observation of optical phenomena and coming up with interpretations of their own. Hadzibegovic and Slisko (2013), suggested an instructional strategy which could be used to address alternative conceptions in optics in university students. In their view, students must be engaged in active learning. Active learning being understood to be an activity that might involve students in in-class observing, writing, experimenting, discussion, solving problems, and talking about to-be learned topics. The strategy involves designing an interactive lecture demonstration where students can learn from a lecture experiment. Students would predict the outcome of the experimental demonstration, observe the experiment, and write the outcome. The outcome of the experiment is compared to the student prediction. The teacher then guides students to use justified explanations to evaluate the outcome of the experiment against their predictions. The activity also involves students answering a sequence of questions on worksheets by writing and drawing. This way the instructor can evaluate conceptual change related to light reflection, refraction, and image formation.

This strategy is much more helpful in addressing alternative conceptions students have in terms of the role of the screen, where students should realise that a screen is only a tool of convenience for the observation of real image points in space (i.e., aerial image). A real image does not need a screen to exist but can exist in air space as an aerial image, independent of the screen. A practical demonstration may be much more effective, where students are asked to practically observe an aerial image with their own eyes placed at a position slightly beyond the point where the image is formed (i.e., without the aid of a screen) (Kaltakci-Gurel, Eryilmaz, & McDermott, 2016). Questions regarding the difference between what students observe with a screen in place and without the screen in place, whether the image can still be observed with the screen and without the screen when one shifts from the original location of the aerial image, should also be raised. Students should come to realise that the position of the real image is only one. Further suggestions from Kaltakci-Gurel, Eryilmaz and McDermott (2016) consider provision of more the inquiry-oriented type laboratory experiences to develop the ability of students to relate theoretical knowledge to practical context, a discussion of textbook explanations and representations since textbooks may be another source of alternative conceptions for students. An example is when a textbook fails to include and explain the role of the eye in image formation using a mirror or a lens, students may end up thinking that the presence of the eye is only necessary for observing the image, but not as part of the formation of the image process (GÜREL, & Eryilmaz, 2013). Thus students may end up thinking the image is always formed and stays in the mirror, whether the eye is present or not.

In this study two strategies were used to address misconceptions in geometrical optics. The first one involved use of collaborative work through group discussions in which students worked on a set of problems provided on a worksheet. After going through assigned problems, solutions to these class problems were openly discussed before other classmates and the instructor, with the instructor probing areas where misconceptions were likely to arise. The second strategy was using laboratory practical investigations, and students had to write reports justifying their results.

2.4 FLIPPED CLASSROOM INSTRUCTIONAL APPROACH

2.4.1 Conceptual and historical foundations of Flipped Classroom Approach (FCA)

The origins of FCA as per literature surveyed is presented to trace the origins of this concept to help understand what the concept is about. It helps in understanding what the originators of the idea had in mind, and how the transformation to the final terminology currently being used was arrived at. It also helps to look critically at how the concept is being used currently, whether the same original ideas are still maintained or not. That way one gets a broad view of what the concept is about and can use it as a teaching framework with greater understanding. To take an example, the current use of the concept of FCA is defined by Kurtz, Tsimerman and Steiner-Levi (2014) p 171 as "In its essence, learners prepare for classes by watching videos away from class, allowing the classroom encounter to focus on discussion, exercises, and discourse on the basis of what students learned from the videos." To them, there must be a video component for the approach to be flipped, while to others this may not necessarily be so. How this definition is arrived at requires us to understand the concept in its essence as it originated from the past. The same authors cited above acknowledge the origins of FCA to be the work of several researchers and teachers. In the following paragraphs, excerpts of literature have been compiled and placed chronologically to show where the concept began and where it ended up currently.

According to the report published by the University of Waterloo, in the white paper developed by the Centre for Teaching Excellence (CTE White Paper, 2015), regarding the practice of teaching and its historical background in higher education, it shows that universities came into existence in Europe about a thousand years ago. There was no printing press and writing material was very scarce. So, information was shared mainly through talking before an audience of learners, and the students were supposed to remember most of what was said since they could not take notes. The mode of teaching was the lecture method or transmission pedagogy. There were no books until 500 years later when the printing press was invented. Even after books were introduced still the lecture method persisted. The paper continues to point out that knowledge probably by then was understood to be a product that could only be poured into a student's head, and the student was just a passive recipient.

The transition from the lecture approach to the FCA approach seems not to be well defined. According to Berrett (2012), flipping the classroom was there for decades in humanity courses where students had pre-readings before class, while class time was devoted to draw out themes. Law students had to prepare before class time so that they could be able to respond to the questions raised by their professors and he method of class discussions in the humanities was Socratic Method. Thus, there was preparation before class and questioning for understanding the material studied outside class was conducted in class. This is the idea behind the FCA. Gibbons, Kincheloe, and Down (1977), however, does not specify exactly when this flipping the classroom started or took place in the humanities.

A similar approach, though it was not termed flipped classroom was reported by (Gibbons, Kincheloe & Down, 1977). Gibbons described a new teaching technique that was introduced around 1973-1974, called Tutored Videotape Instruction (TVI) technique. It was introduced at the University of Stanford in the United States of America, for its off-campus graduate science and engineering students. These students had to undertake their studies at a remote campus from the main university campus and were assisted by para-professional tutors provided by the university. The technique allowed students to watch video lectures prepared by their professors in the absence of the professors, but no follow-up specific class sessions were conducted with these professors to discuss the material presented. Instead, tutors were provided so students could watch the video lectures in the presents of the tutor. The idea was that if students had questions on what was being presented, they would stop the video lecture at their own free will and then discuss the concept in question with the tutor. After the discussion the students would proceed to watch the material being presented. The tutor was there not to teach but to help clarify questions arising from the students as the video lecture session was in progress. The technique was considered quite effective as it produced much better results than students at the main campus who were having normal sessions with their professors. Another interesting factor was the students exposed to this method of teaching had marginal academic qualifications, which would have denied them admission to the University of Stanford graduate program.

Though Berrett (2012), as discussed in one of the earlier paragraphs could not point out exactly when flipping the classroom started in humanities, he was able to point out that the teaching of the STEM subjects, specifically calculus course in mathematics, has been taught using the flipped method since the mid-1990s at Michigan University in United States. The teaching process involved a pre-reading before class time, a brief lecture in class, followed by discussion of questions on the reading done out of class, then a demonstrative example. Thereafter students made presentations of their preparations done before class time. Finally, a brief lecture would be given to conclude the in-class session. The approach was implemented after providing training on how to flip the classroom to the novice instructors, which involved a one-week course on flipping the class, weekly meetings, and regular class visits by the senior professors. The main idea behind the teaching strategy was to ensure students understood the underlying concepts of the calculus course undertaken.

A similar teaching approach to the same effect to what Berrett (2012) reported was introduced by Mazur in 1990. According to Mazur (1997) in his article on physics teaching titled- Understanding or memorisation: Are we teaching the right thing, he describes a new method of teaching called Peer Instruction which he started in 1990. His intention when he came up with this strategy was to improve students' understanding of physics concepts. The idea was born after he had read an article about how students learn. The article had highlighted the fact that students can solve physics problems procedurally, but this does not mean they understand the underlying concept. The nature of Mazur's Peer Instruction was that students had to prepare before coming to class, by studying the lecture notes he prepared beforehand, and also their textbook content. During class time he would concentrate in developing conceptual understanding by engaging students actively in responding to conceptual questions. Students would independently think about the answers to the questions he poised, then provide their responses to him, which he would record in terms of the percentage that go the correct answers, and that did not. This would allow him to judge whether the concept under discussion was understood or not by the majority of his students. He would then provide another opportunity to the students to discuss in pairs the same questions and respond again. Comparing performances before and after pairing the students enabled Mazur to judge the extent to which students had understood the concept and would then decide on how to address their misconceptions. Mazur wanted the students to focus on understanding the underlying concepts instead of the procedural aspects of solving physics problems. By making students actively discuss the concepts in class the approach had a positive impact on both conceptual understanding and procedural solutions promoted by textbook problems.

Mazur was not the only one experimenting with his peer teaching approach in the 1990s. In 1998, Walvoord and Anderson focused on how class time could be made effective in social sciences such as history (Walvoord & Anderson, 2011). Their argument was that teachers should teach according to the criteria by which they will evaluate the test they give to their students. The challenge according to them, was how to prepare the students for class so that one can teach effectively in class in line with that criterion. They proposed that students should read before coming to class the material to be discussed in class, so that the class time could be used to actively analyse and argue concepts based on the reading assigned to students to prepare earlier on before class time. They described events that would take place during class time in this way: "The authors call this broadly the processing part of learning, where students synthesize, analyse, compare, define, argue, or solve problems based on the materials to which they have been exposed" (p 6). The preparation stage called the first exposure part. Development of the exposure part was to be done by writing a short summary of the assigned reading, which could then be graded in class during discussions without necessarily marking it and giving comments. Discussion in class is based on the preparation done during the exposure time. This processing stage has a built-in assessment where the teacher becomes familiar with the way students are thinking and learning, thereby enabling the teacher to address areas where students need help. The method was referred to as interactive assignment-based model. Thus, teaching based on lectures is eliminated. Class activities are carefully planned based on goals linked to learning and assessment.

Both the works of Mazur in 1990 and Walvoord and Anderson in 1998 explained in the previous paragraph bear similar characteristics to the FCA, though the researchers did not call them FCA as such. The first term like FCA appeared in the works of Large, Platt and Treglia (2000) and was called the inverted classroom. The term was used to describe the instructional approach they were using at University of Miami. Their intention was to come up with an alternative instructional approach that appealed to all types of learners in the subject of economics, following recommendations from previous research. By then students were grouped according to three learning styles: dependent learners- being those who require a lot of direction from the teacher, collaborative learners- those who work best as part of a team, and the independent learner-who does his best when left alone to his or her own devices. According to Large, Platt and Treglia (2000, p. 32), inverting the classroom accommodated the various learning styles of these groups of students, with multimedia as its cornerstone. In their view "inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa". Inverting the classroom provided students with various options to learning that led to an outcome targeted by the teacher, thereby giving the teacher more time to plan for the same outcome.

At the time when Large, Platt and Treglia (2000) published their work on inverting classroom, Baker (2000) also published a conference paper about a teaching approach which he referred to as Classroom Flip which he started in 1998. What prompted him to come up with this new approach was the new trend in education at the time. According to Baker (2000), the educational philosophy was changing due to new research findings on how people learn from cognitive science which viewed students as "active discoverers of knowledge who learn best in a social setting in which faculty serve as mentors" (p. 9). The second trend was about new technologies that were being rapidly produced which allowed for active participation. He wanted to bring a connection between the new technologies and classroom delivery at campus level, in a way that could transform classes so that the student in a face-to-face class can be an active participant in a lecture instead of being a passive participant. His "Classroom Flip" model considered the strengths of the cognitive philosophy on how people learn, and the aspect of active participation offered by the new technologies. By harnessing these strengths to the traditional lecture method, the birth of "Classroom Flip" was possible.

The transition from Classroom Flip of Baker to Flipped Classroom took place in 2010 (Bergmann, 2011) when Dan Pink was trying to accredit the approach to Karl Fisch who had been using the approach and had made video lectures viral on You Tube. However, Karl Fisch learnt of the approach from trainees of Bergmann and Sams (Bergmann, 2011). In 2007 Bergmann and Sams recorded their lessons for their students who were not attending classes due to various reasons (Bergmann, 2011). They also did not want to keep teaching the same content repeatedly each time some of their students missed classes. The approach was adopted by many educators as it gained popularity on You Tube which had just started. Before Dan Pink coined the approach Flipped

Classroom, they referred to it initially as the Pre-Podcasting model, in relation to the distribution process of the videos which was being done at the time as podcasts, but later changed the name to Reverse Instruction. Dan Pink initially called the FCA approach Fisch Flip, but this was discouraged by Fisch.

2.4.2 Working definition of FCA

Flipped classroom is a concept that has been interpreted in various ways, leading to various terms being used to describe it such as: flipped learning, inverted classroom, reverse teaching, backward classroom, lecture flipping or Thayer method (Nwosisi, Ferreira, Rosenberg & Walsh, 2016). The failure to have a single specific definition reflects the term is a broad one with flexibility to accommodate various instructional methods. It can therefore be referred to as an instructional approach. In all the various interpretations studies so far conducted on it, there are two main commonalities: class time is dedicated to enhancing student understanding of subject matter, unlike the traditional approach which focused on transmission of information, while homework time in the traditional case is now used in flipped classroom approach for lesson preparation-which might be done with the help of technology or not. However, for purposes of the study, there is need to define what is understood as flipped classroom approach. Three definitions from literature are provided and analysed in order choose the most appropriate for the study.

According to Sankey, and Hunt, (2014), flipped classroom provides students with online resources which are designed with a particular purpose in mind, together with some learning activities for practice, in preparation for classroom discussions, where application and consolidation of concepts will be done according to specified learning outcomes. In their view, this is meant to infuse pedagogy and technology. Thus, allowing many students to benefit from using technology-based processes of information dissemination out of class, while class time provides deep learning opportunities through application and consolidation of concepts. Flipped classroom in this case is a redesigning the curriculum to engage students actively with content and to invoke deep learning which can be recalled, used and last long after studies are completed. The preparation phase may use videos that explain concepts, structure of content, and skills as defined in content goals. In their view, the classroom discussions should resemble a workshop of learning, where the teacher is on hand giving practical assistance and checking on progress, picking up and rectifying common errors.

Demirel (2016) describes the flipped classroom as an educational teaching model that reverses the traditional teacher centered way of teaching, to one that is learner centered, that may (or may not) use technology (in form of short videos of 10-15 minutes duration) to learn material as homework activity in preparation for class time, while class time is used for application of the material learned through active leaning and collaborative learning strategies. Flipped classroom here is an instructional strategy blending technology and active learning. Damirel explains the model allows students to set their own pace of learning material out of class and saves class time for a deeper interaction with the material. The main idea in this instructional design is to shift the traditional mode of content transmission from class time to outside the class through videos or other means. There is reorganisation of all aspects of instruction to maximise the use of time and does not require inclusion of technology for it to qualify as flipped classroom. Students can read prescribed material prior to class time, as a way of engaging with concepts prior to class time. The teacher is the "goalkeeper" by guiding students through what they should know and be able to do. The cycle does not end in class discussions, but after class students still need to use feedback gained during class time to further their learning, by reviewing concepts that were not fully understood in class, and doing more exercises, thus completing the cycle. A graphic representation of the whole cycle of flipping the classroom is shown figure 2.2 below.

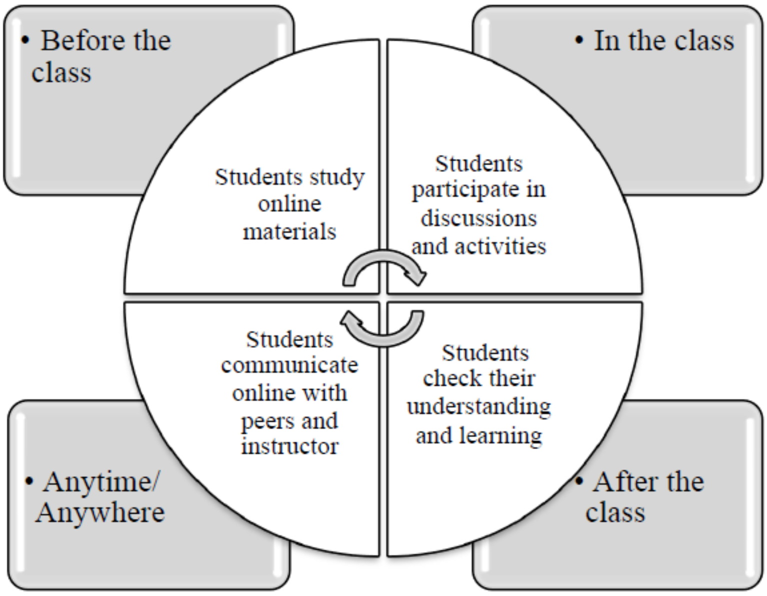


Figure 2. 2: A flipped classroom model for developing universities (Nat, 2015, p. 601)

On the other hand, Bishop & Verleger (2013, p.5), in a survey of research on flipped classroom came up with the following definition:

"We define the flipped classroom as an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom".

This definition accounts for the popularity of the term "flipped classroom" in literature. After Bergmann and Sams (2012) posted their lessons online the term became popular being associated to a teaching approach combining technologically supported prior classroom preparations and in-class activities designed for enhancing conceptual understanding and application.

Sankey and Hunt (2014), Damirel (2016) and Bishop and Verleger (2013), all three agree in principle that:

- there must be in-class activities and out of class activities.
- the out of class activities serve as preparation for the in-class activities
- the in-class activities are meant to deepen subject matter understanding of students.
- there is inversion of time and its purpose

However, Sankey and Hunt with Bishop and Verleger, prefer using technology only for preparing in-class discussions, while Damirel, considers both type of activities- those that involve technology, and those that do not involve technology, whichever is used to prepare for the in-class sessions, to be the other component of flipped classroom. For this study, the definition provided by Bishop and Verleger is relevant, if compared to the characteristic of the current crop of students who are highly technologically literate and spent most of their time on their technological gadgets. As such, this definition is more suitable than the broad definition of Damirel (2016).

One of the tenets of FCA underpinned in its definition is that it takes advantage of the technological literacy of the current crop of students. Technology is taken advantage of by allowing first contact with new ideas to be done out of the classroom time, placing it to the individual's time and space, using technological tools. This inversion of the traditional mode of instructional delivery allows for more time to be created for a classroom environment where active learning that deals with advanced ideas of scientific conceptions can take place. In this way FCA plays an important role in instructional design. Thus, before discussing the different models of FCA showing how it has been used to restructure instruction, the following section briefly discusses its role in instructional design.

2.4.3 The place of flipped classroom in instructional design

An interesting point to note in these definitions is that flipped classroom is about how to conduct instruction to develop greater understanding of a subject matter. Flipped classroom is a specified instructional strategy within the components of a course design. Instructional design is mostly the component that determines the success of a course design. According to Institute of Electrical and Electronics Engineers (IEEE) (2001, p.1):

> *"Instructional design is the process through which an educator determines the best teaching methods for specific learners in a specific context, attempting to obtain a specific goal".*

This definition helps identify the role played by flipped classroom approach in the present study, which is to come up with a set of methods and assessment tools or principles for achieving instructional goals for geometrical optics in a particular case study. The stress is on the process involving a set of possible interactions and the educational environment. Thus, flipped classroom represents an expansion of the curriculum and not merely a re-arrangement of the sequence of activities. Interactive group learning activities inside the classroom is an environment where the instructor assess the extent to which students have mastered the material, and take appropriate measures if results are not according to learning objectives. The assessment process itself to measure student understanding, engages students in actual practice of developing cognitive skills planned by the instructor. When students are asked to make use of material studied in novel situations, as they confront challenges, learning take place. Discussions among students and the instructor in seeking solutions to problems, make students attentive and engage with material. Thus, there is increased interchange among students as well as with the instructor (Khandve, 2016). A good picture of what flipped classroom proposes to achieve during class time through active and interactive learning is described by Kutbiddinova, and Eromasova (2016, p. 6557):

> *"The active and interactive methods allow sharing information, receiving feedback, solving together the arising problems, simulating the educational situations, evaluating one's own behaviour and the actions of other participants, diving into the real atmosphere of business cooperation in solving problematic issues".*

A lot therefore happens in class regarding student learning. There is much more of what the student is expected to do. There is an expansion of the curriculum. The fact that there is a re-arrangement on sequencing of activities brings in the aspect of instructional design, to enable effective use of class time through active and interactive learning strategies. When a teacher is involved in flipped classroom, he (or she) needs to have knowledge of instructional design as well (Estes, Ingram & Liu, 2014). The process requires the teacher to manage subject matter in form of digital content. The teacher therefore has to be a media developer. The teacher has therefore many roles-being a subject matter expert, instructional designer strategies expert, and a media developer.

2.4.4 Design approaches for flipped classroom instruction

This section describes five studies that attempted to show how to design FCA, how principles that can further guide the design of FCA could be obtained, how student performance changed due introduction of FCA, how to design an FCA-based intervention, how other aspects of learning other than quantitative performance were investigated. At the time this study was conducted, few studies in literature investigated these afore mentioned aspects of learning. The five studies examined in this section were chosen on the basis that they were some of the few studies that attempted to provide details on how FCA can be conducted, designed and its design principles obtained.

O'Flaherty & Phillips (2015) acknowledged at the time of their publication, that no single model of the flipped classroom applicable to all disciplines was available except the core features that include: delivery of content in advance (the pre-recorded lecture), educator awareness of student's level of understanding, and the need to focus on higher order learning during class time. FCA research has become a field of study and is gaining momentum as research involving different types of its design is being conducted. This section examines five works in which FCA has been designed and implemented to improve course delivery for a gainful student learning. According to Reigeluth, Beatty and Myers (2016, p. 250), there are descriptive models that literature suggest but they lack evidence to "provide grounds on which to make decisions regarding the design of flipped instruction". These models are not based on "research results to support specific design principles for flipped instruction". It is with this understanding that the five works discussed in this section are real research studies from which the design principles they employed may be examined to enrich ideas being implemented in the current study for a course design for flipped instruction.

Teaching is meaningfully achieved if information intended for the student is appropriately disseminated using means that enable the student to make meaning out of what has been delivered. This calls for the instructor to be a designer. The instructor can use a model designed by other researchers, or modify what other researchers have produced, or can be innovative enough to come up with a new model to address the situation at hand. Martínez, Lombaerts and Celaya (2017) recommend on adopting specific instructional models when designing one's instruction, especially when the instructor wants to achieve active learning in the class. Active learning involves the use of strategies such as problem solving, debates, discussion, or any non-passive activity permitting the student to physically and / or mentally work towards achieving a defined learning goal. A model, therefore, should permit planning of in and out of class activities that involve elements of interaction (i.e., *interaction between student & instructor, student & course content, student & student*) and exchange of information, to allow activation of learning. It helps to bring coherence between teaching and learning styles of teachers and learners respectively, as well as coherence between learning goals and assessment. These elements can be successfully aligned if the appropriate model is used.

Martínez, Lombaerts and Celaya, (2017) carried out a study on FCA with 5 undergraduate students in a computational physics course. They used Fink's model within the conceptual framework of FCA to come up with an FCA instructional model for delivering a course. Fink's model demands one to address four key elements when undertaking any form of instructional course design. The four elements are: (i) *learning goals or outcomes* - which define what the teacher is expected to achieve, (ii) *teaching and learning activities*- which define what the teacher is supposed to do to accomplish the goals / outcomes, (iii) *feedback and assessment*-which serve to monitor or control the teacher if he / she is operating within the defined guidelines / goals, and (iv) *the situational factor*-which has 5 sub-elements of its own namely: *the specific content of teaching and learning situation*-which is concerned about the way the course will be delivered taking into consideration the number of students in class, *general context of learning situation*-which is about course expectations that can help students acquire the relevant knowledge as well as contributions to the understanding of the next course on which the current course may be a requisite, *nature of subject*-which is about whether the course under study is theoretical, practical or a combination and the need to understand the prior knowledge level of the students for the course, *characteristics of learners*-which refers to the life situation of the students, the learning goals they are expected to master, students' expectations and learning styles (i.e. whether they are imaginative learners, analytic learners, common sense learners or dynamic learners), *and characteristic of teacher*-which refers to the knowledge level the teacher has about the subject, as well as beliefs and values the teacher has about teaching and learning that tends to guide his / her teaching style. All the elements in the model are interrelated as shown in Figure 2.3.

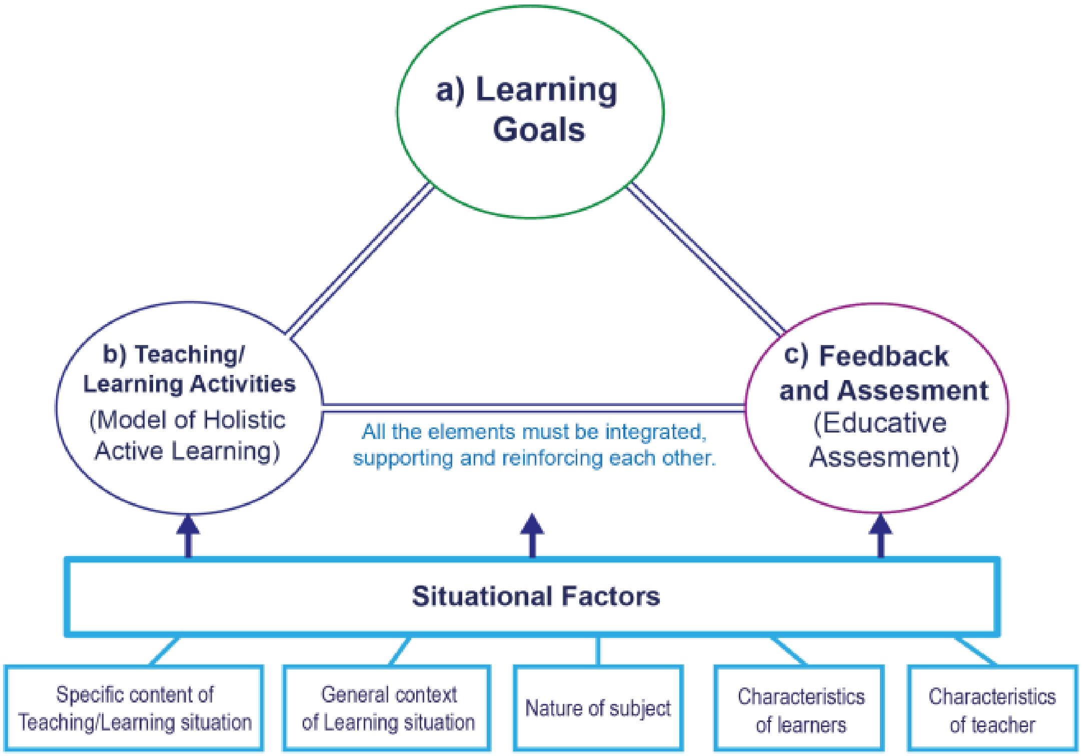


Figure 2. 3: Model for integrated Course Design (Martínez, Lombaerts & Celaya, 2017, p.2326-4)

According to these authors, the new way of teaching and learning was well received by the students as students shifted from a passive attitude to an active attitude. All students received good grades on the tasks they were asked to accomplish. Students adopted very fast the way of working, making it easier for the instructor to facilitate the course. This made the authors realise that students seem to be open to new approaches to learning, a factor which can be taken advantage of to boost student learning effectiveness. It seemed the results of the study supported their design principles for a flipped classroom instruction. In their view flipped classroom model promoted active learning leading to a learning that was effective. From the survey they conducted with students, students pointed out areas of need that could improve their design of the flipped classroom and these were: an increase in collaborative work, giving students greater opportunity to engage in the learning process in the classroom or by social networks, and the promotion of activities that have impact beyond a course itself.

Although this flipped classroom instructional model design, based on Fink's model by Martínez, Lombaerts & Celaya, (2017) seemed to have yielded encouraging or positive results, there are still a number of questions that may be raised as regards the extent to which the study was successful: firstly, the study involved very few students (only 5), and the results may not be the same if the study was conducted with a larger group of students of a wider spectrum of characteristics. This is an important factor that needed scrutiny in their discussion but was not mentioned. A lager group of students is not easier to handle as the logistics for handling such a group are more demanding than in the case of a smaller group. Secondly, their students did not take a written examination but both formative and summative evaluations was in the form a course project. The authors fail to provide explicitly what was done for the in-class and out of class activities of their FCA model. There is a possibility that the outcome may have differed had the evaluations been in written format. The evaluation process does not reflect rigorous assessment methods needed to make a reasonable conclusion on the effectiveness of the designed FCA model. Overally the authors in their conclusions did not also draw upon the recommendations provided by their students to provide a new structure of a generic set of principles for designing a flipped classroom instruction. It seems their intention was focused on student achievement and opinions, and not the guiding principles that could come out of the results of their study for future use by others. So, they fail to articulate what guiding principles can be deciphered in general out of their instructional design model for the benefit of others who may be intending to teach the same course or other courses, as pointed out by O'Flaherty & Phillips (2015), as one of the gaps in literature.

Kim, Kim, Khera and Getman (2014) conducted a study in which the intention was to finally propose a set of design principles for a flipped classroom approach that could be used in diverse disciplinary contexts. Their study was an attempt to fill a gap in literature where the focus of most studies was in designing technology enhanced student-centered learning environments using the flipped classroom instruction. The study was conducted with 115 student participants who were enrolled in three different disciplines namely: engineering (52), social studies (48) and humanities (15), as well as three instructors. A Revised Community of Inquiry (RCOI) model was used to create the flipped classroom design framework. The model consists of four elements that are mainly considered to contribute to a successful learning environment, and these are: cognitive presence, social presence, teaching presence, and learner presence. According to Pool, Reitsma and Van den Berg (2017) these four elements may be defined as follows: cognitive presence- refers to the process whereby students construct meaning through collaborative inquiry, social presence- is when students are able to relate with other community members at personal level, teaching presence- is the force that brings together all the elements in the process, structures and leads the process, in such a way that the process is constructive, collaborative and sustainable, while learning presence- refers to the way students are proactive in the use of specific processes such as setting their own goals, selecting learning strategies, and monitoring of their personal effectiveness. Kim et al, (2014) used a mixed method approach in their study where data collected included surveys in form of closed ended questions (quantitative) as well as survey in form of open-ended questions, interviews, instructor reflections and document analysis (qualitative). The quantitative data was analysed first in order to identify the overall features of the flipped classrooms, while the qualitative data was used to extract the design principles. In their results, six design principles emerged from data themes, as new suggestions for creating the flipped classroom. These principles were as follows:

- *Provide clear connections between in-class and out-of-class activities*- which refers to the importance of supporting (or connecting) in-class activities with appropriate online content and activities, otherwise students may fail to engage with some of the in-class activities thereby failing to successfully achieve the learning goals.
- *Provide clearly defined and well-structured guidance*- the instructor must provide clearly defined and well-structured guidance as well as scaffolding for all cognitive activities for the flipped classroom.
- *Provide enough time for students to carry out the assignments*- students should not be rushed to complete tasks or activities but ample time must be allocated to them so they can apply the knowledge, information and skills acquired online.
- *Provide facilitation for building a learning community*- the instructor should facilitate the creation of a learning community where students acquire new ideas by learning from one another. That is there should be a well prepared and appropriate guidance for student collaboration that factors in group dynamics, roles and levels of participation as well as satisfaction with grading scheme.
- *Provide prompt/adaptive feedback on individual or group works*- instructors need to provide greater and immediate feedback to students be it for group work activities, how to link out of class preparation with in-class activities, providing feedback and instructional support according to students' different needs.
- *Provide technologies familiar and easy to access*- it is important to use familiar and easy to access technologies, and to develop acceptable standards when developing and delivering online content, such as a short video focusing on a specific topic. In other words, importance should be given to how to integrate technology into pedagogy than the mere use of it.

Overally Kim et al, included three other design principles from Brame (2013), such that in total, their design propositions for a flipped instruction were nine. Brame proposed the following design principles for a flipped instruction: first - *provide an opportunity for students to gain first exposure prior to class*, where students are given the opportunity to prepare for in-class activities by watching and exploring online materials such as video lectures, outside the classroom at their own time of convenience; second- *provide an incentive for students to prepare for class*- a monitoring mechanism for students to prepare for in-class activities is needed since not all of them tend to prepare as expected by the instructor. As such an incentive such as a quiz which is graded and contributes to the overall grading of the student performance become necessary as an incentive to prepare for the in-class activities; and third- *provide a mechanism to assess student understanding* – for out of class preparation the quiz may help also to check on students understanding, while during class time through discussions the instructor may assess students understanding. However formative tests among other mechanisms must be used to assess student understanding.

In conclusion, the principles proposed by Kim et al provide a meaningful framework for one to design flipped classroom instruction. The set of principles can be used as a guide to structure a flipped classroom instruction, unlike in the case of the study discussed earlier on of Martínez, Lombaerts and Celaya, (2017), which does not show how the research results support their design principles. In the study of Kim et al though, the authors did not include participants' performance (i.e., achievement scores) such that the impact of this model could be evaluated within each of the disciplines investigated. It is also important to note that in both studies of Kim et al and Martínez, Lombaerts and Celaya, there are no details of how the models they used to structure their flipped instruction were used during the instructional process. For example, they do not show the role played by each element or component of the models in the design of out of class activities or in-class activities. This lack of clarity may make it difficult for instructors to know exactly what to do when designing the flipped instruction activities, worse still in the case of Martinez, Lombaerts and Celaya' s model where they did not even summarise the key tenets of their own final model that resulted from fusing Fink's model and flipped instruction.

Aşıksoy and Özdamlı (2016) conducted a study to determine the effect of FCA on three aspects of learning, namely- learner achievement, motivation, and self-sufficiency. The study was an innovation of Keller's Attention, Relevance, Confidence, and Satisfaction (ARCS) Model to incorporate FCA's general conceptual framework, mainly the two components of in-class and out of class activities. Keller's model defines four main components, namely- *attention*- meant to develop student interest and attention on the content being studied, *relevance*- focuses on making the student understand how useful the content will be post school phase, *confidence*- speaks on developing success expectations in the learner so the learner can be able to control the learning process by him/herself, and *satisfaction* – intended to make the student satisfied with his/her achievements during the learning process.

The study was carried out with 66 undergraduate university students. It was an experimental study in which the students were divided into two groups, with one group of 30 students being taught using the traditional lecture approach, while the other group of 36 students were taught using the FCA. The ARCS and the FCA principles were fused as shown in table 2.1 shown. The out of class and in-class activities were structured for a 55 minute, once per week session as follows:

Table 2. 1: How the ARCS was merged into FCA.

FCA's main components	**Activities**	**Keller's ARCS components**
Out of class activities	Watch video lectures and answer imbedded quiz with immediate feedback to student through answer keys- Quiz made part of course grade to motivate students to study and to ensure preparation before class is done	Not indicated
In-class activities	Daily life event used to introduce class	Attention, Relevance & Confidence
	Simulations	Motivation
	Solving problems with peers	Confidence
	Discussion with peers	Confidence
	Positive reinforcement	Satisfaction
After class activities	Not indicated	Not indicated

According to the Aşıksoy and Özdamlı (2016), the study results showed a greater achievement in academic performance of the FCA group, with post- test scores significantly higher than those of the control group. A semi-structured interview was also conducted with the FCA group to seek their views over the ARCS components, and the results revealed a positive influence.

Aşıksoy and Özdamlı (2016)'s model does not provide much out of the general conceptual framework of the FCA, i.e., in-classroom activities for active learning and a deeper understanding, while out of classroom activities are for acquaintance with basic knowledge. This is unlike Martínez, Lombaerts and Celaya (2017) who went to a greater extend of using another model meant for designing instructional delivery. Even though they did not provide the key components of their design, Martínez, Lombaerts and Celaya, (2017)'s model can be used to guide one to come up with his/her own due to the powerful design model- Fink's model. The ARCS model seems merely to work at motivational level and does not address the crucial components related to conceptual understanding. However, its merit lies in the fact that it attempts to show how the elements of the underlying model (ARCS) could be fused with the two main ideas of flipped classroom-out of class and in-class activity design. This is not reflected in Martínez, Lombaerts and Celaya, (2017)'s model, neither is it also reflected in Kim et al model.

Lo, and Hew (2017) conducted an exploratory study on flipped classroom at a secondary school in Hong Kong. Their objective was to explore how the design and implementation of the FCA model could be improved by examining the teacher and students' perception of the FCA model after its implementation. The participants were 37 form 6 students who were divided into two groups of 13 and 24 of underperforming and high ability students, respectively. Both groups were exposed to FCA in which Merrill's (2002) *First Principles of Instruction design theory* was used as the theoretical framework for implementing the FCA. The theory has four key elements, activation, demonstration, application, and integrations. These elements were used to structure the FCA as shown in the figure 2.4 below:

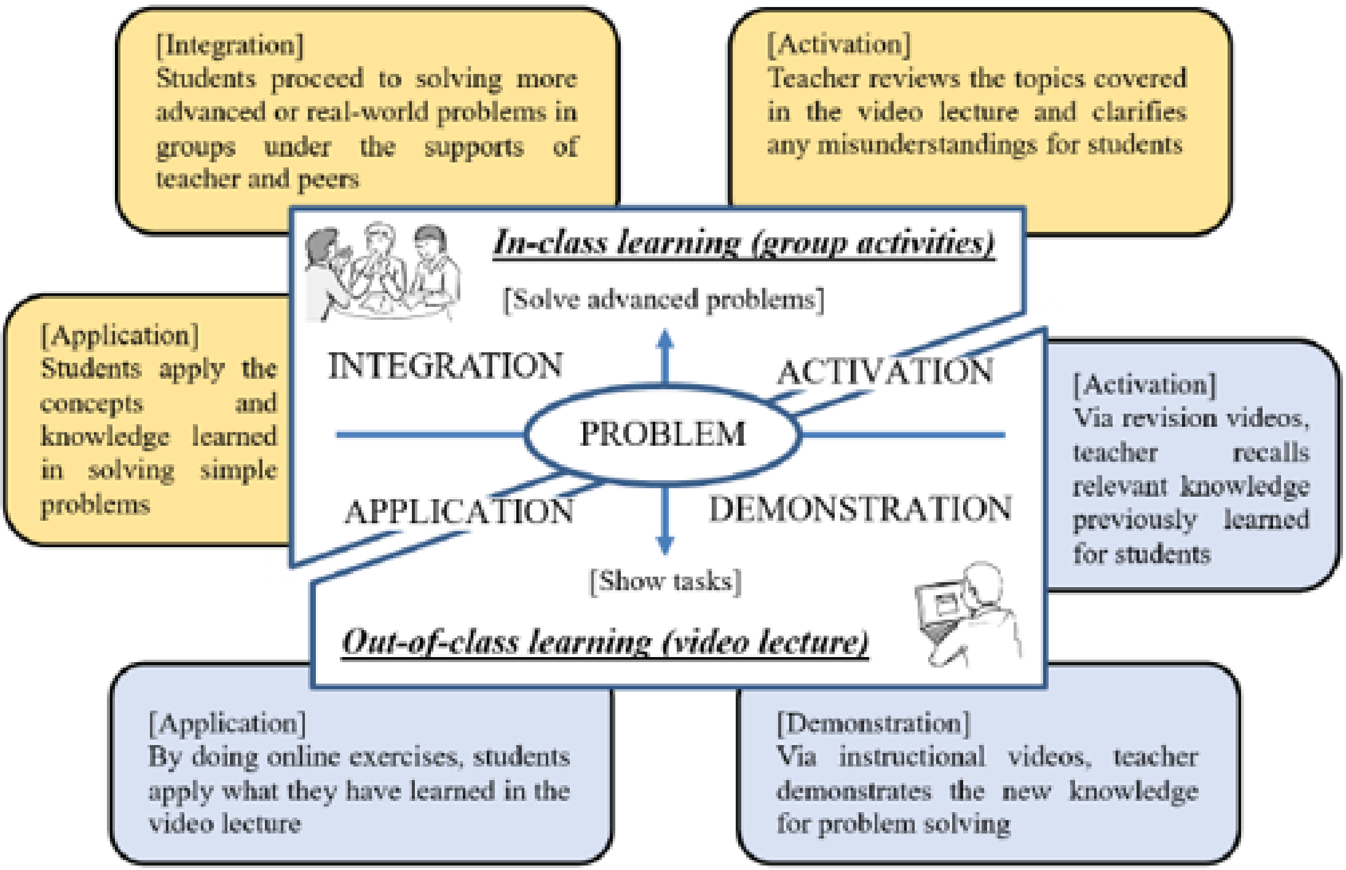


Figure 2. 4: Design framework for a flipped classroom (Lo & Hew, 2017, p. 224)

Merrill's (2002) *First Principles of Instruction design theory* consists of five principles which are represented as a conceptual framework in Figure 2.4. These principles, fully stated are as listed below (2002, pp. 44-45):

1. Learning is promoted when learners are engaged in solving real-world problems
2. Learning is promoted when existing knowledge is activated as a foundation for new knowledge
3. Learning is promoted when new knowledge is demonstrated to the learner
4. Learning is promoted when new knowledge is applied by the learner.
5. Learning is promoted when new knowledge is integrated into the learner's world.

According to Merril (2002), the principles are for problem centered instruction. The first principle relates to the concept of a problem located at the centre of the conceptual framework of figure 2.5. It defines what is understood as a problem (p.45):

> *"The definition of a problem varies among theorists. For some, a problem is engaging in some form of simulation of a device or situation. For others, it merely means being involved in some form of real-world task. I use the word problem to include a wide range of activities, with the most critical characteristics being that the activity is some whole tasks rather than only components of a task and that the task is representative of those the learner will encounter in the world following instruction".*

In addition to showing the conceptual framework of Merril's first principles, figure 2.5 also shows how FCA model was carefully integrated into this framework with respect to each of the other four principles by Lo and Hew (2017). Merrill's principles are about the fundamental strategies used in the teaching learning process, *activation, demonstration, and application*. Thus, out of class activities involved; (i) students watching the video lecture, in which the teacher showed them firstly the task to be accomplished after going through the mini lecture, (ii) followed by a review of the basic concepts by the teacher, and (iii) lastly a demonstration of how this basic new knowledge, strategy, or procedure for solving the problem can be used. To promote the learning, students were then required to answer a simple online quiz, by applying what they learned in the video lecture. The in-class activities involved (1) teacher reviewing topics covered in the video lecture, (2) clarification of student misunderstandings, (3) concept application by solving simple problems individually or in pairs, and (4) finally the solving of real – world problems in groups under teacher and peer support.

Data analysis in this study involved the use of t-test, in which the results of the first group of underperformers showed a significant improvement from a pre-test mean of 2.77 to a post-test mean of 5.85, while those of high ability students improved from a mean of 2.00 in pre-test to a mean of 8.08 in post-test. Students' opinion about the video lectures was also positive, with a bit of criticism about how feedback from the teacher was handled. Students wanted the online tasks to be provided with explained solutions, or an improved online communication system in which the teacher could clarify aspects they failed to understand.

Lo, and Hew (2017) did not come up with any principles of their own on how to design an FCA model for mathematics or any other subjects such as provided in Kim et al model. However, the way they integrated the design principles of Merril (2002) is recommendable on how to structure an effective FCA for any subject. The principles of Merril were notably applicable to both phases of FCA (out of class and in-class phases). Another important aspect that does not appear in their design relates to their failure to include other components of instructional design such as course goals, assessment, and feedback. Their study, like Aşıksoy and Özdamlı (2016) focused more on how the content should be delivered without provision of checking whether the student is understanding it or not, or whether what the student is getting is in line with the learning outcomes. So, the model is limited to teaching and learning activities unlike Martínez, Lombaerts and Celaya, (2017)'s model which covers learning goals as well as assessment and feedback.

Lee, Lim, and Kim (2017) conducted a developmental investigation on flipped classroom approach with 18 college students. Their intention was to construct and validate a flipped learning design model that could be used as a generic guide at course level for instructors in higher education contexts, particularly to help them when designing online and face to face activities. They used the ADDIE instructional design model to structure their first theoretical model on flipped learning. The ADDIE is an iterative process involving five key phases, where the product of one phase is the starting product of the next phase, with formative evaluation done at each phase so that the evaluation results can help the instructor adjust any of the previous phases. The model is briefly described diagrammatically in figure 2.5:

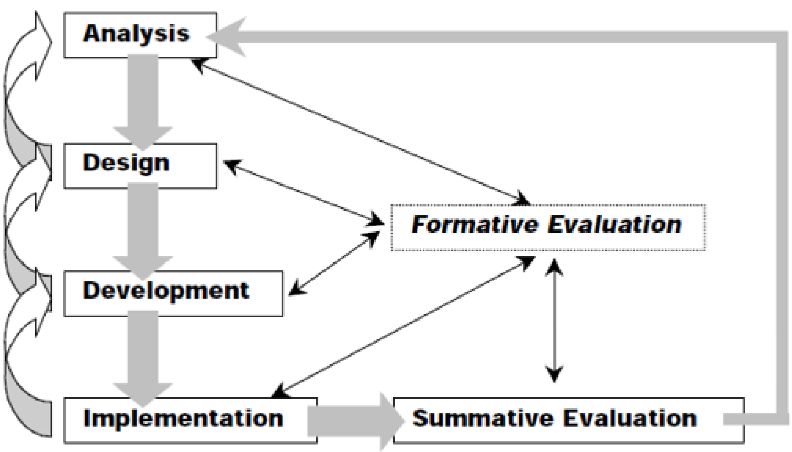


Figure 2. 5: The ADDIE Model (McGriff, 2000, p. 1)

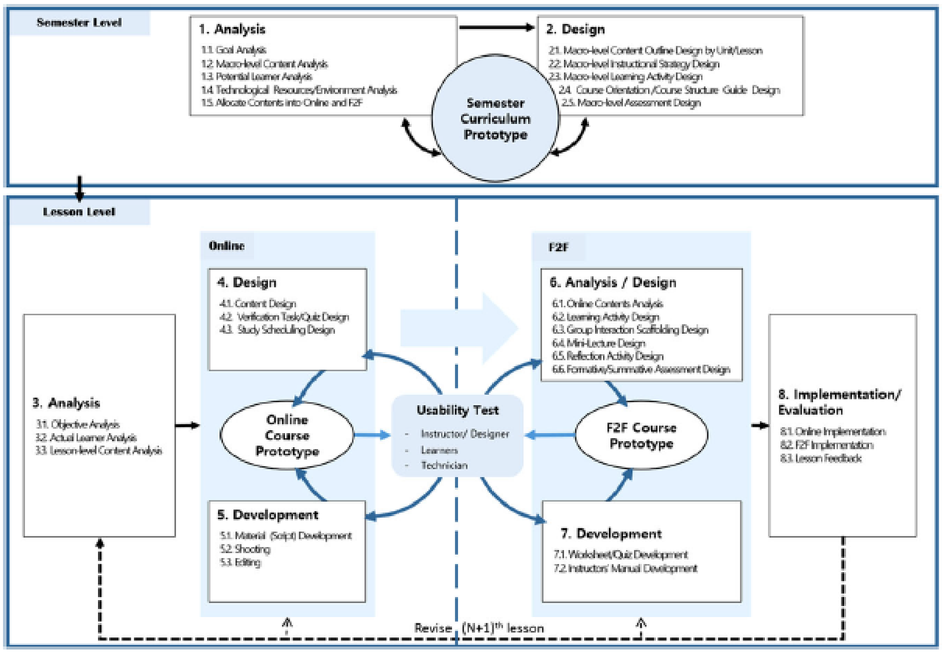
The study took 15 weeks iterating the process twice to come up with the final product model. Each of the iterated models was subjected to various processes of validation. These processes included (i) internal validation involving model usability tests and expert review and (ii) external validation involving pre- and post-semester survey scores measuring changes in students' views about mathematics, student reflection journal scores, a class survey of learners' satisfaction, and follow-up interviews with selected students. Participants included an instructional design team of four members (a university professor and three teaching assistants), and five professors from US and South Korean universities as reviewers. These professors had theoretical expertise and experience in designing and implementing flipped learning in various educational fields namely: physics, mathematics education, electrical engineering, educational technology, and foreign language education. The final group of participants involved 18 students undertaking an algebra course. The results of the study included:

1- A generic instructional model for flipped learning in higher education (figure 2.6), adaptable to various STEM (Science, Technology, Engineering, and Mathematics) subjects.

2- Meaningful increases in students' maturity of mathematical views and epistemological beliefs, reflections, and satisfactions

3- In addition, study skills, presentation skills, collaborative or communicative skills, and inquisitive attitudes toward learning, were also some of the positive outcomes acquired by students.

Figure 2. 6: Flipped Learning design model for higher education (Lee, Lim, & Kim, 2017, p. 441)



To improve effectiveness of the final flipped learning model design, various methods of assessment were employed to bring rigor in the evaluation process of content knowledge and general competencies. The key aspects of this model without details of each section, are presented in table 2.2 below.

Table 2. 2: Outline of the final Flipped Learning Model design (Lee, Lim, & Kim, 2017, pp. 442-444)

The assumptions of the model	
The users of this model are an instructional design team (teacher, instructional designer, teaching assistants, and technological supports) for Flipped Learning. In university-teaching circumstances, a teacher may as well serve as the instructional designer and play all instructional roles when resources are limited. Designing at the course level means designing overall courses ranging from 10 to 15 weeks in duration and consisting of several pairs of F2F classes and online video lectures that should be studied before the F2F class. In the context of the model, "goal" refers to what students need to achieve in real-world circumstances after finishing a course. "Objective" refers to what students need to acquire after having had a lesson. Macro-level has the same meaning as Course Level and Micro-level has the same meaning as Lesson Level.	
Description of the Model	
1. Analysis	
1.1 Goal Analysis	1.3 Potential Learner Analysis
1.2 Macro-level Content Analysis	1.4 Technological Resources
	1.5 Allocate Contents into On and Off
2. **Design**	
2.1 Macro-level Content Outline Design by Unit/Lesson	2.3 Macro-level Activity Design
	2.4 Course Orientation/Course
2.2 Macro-level Instructional Strategy Design	2.5 Macro-level Assessment Design
	2.6 Course Curriculum Prototype
3. **Analysis**	
3.1 Objective Analysis	3.2 Learner Analysis
	3.3 Lesson-level Content Analysis
4. **Design**	
4.1 Content Design	4.2 Verification Task/Quiz design
	4.3 Study Scheduling Design
5. **Development**	
5.1 Material Development	5.3 Editing

5.2 Shooting	5.4 Online Course Prototyping
6. **Analysis/Design**	
6.1 Online Content Analysis	6.4 Mini-Lecture design
6.2 Micro-level Activity Design	6.5 Reflection Task/Assignment Design
6.3 Group Interaction/Scaffolding Design	6.6 Formative/Summative Assessment Design
7. **Development**	
7.1 Worksheet/Quiz Development	7.2 Instructor's Manual Development
	7.3 F2F Lesson Prototype
8. **Implementation/Evaluation**	
8.1 Online Implementation	8.2 F2F Implementation
	8.3 Next Lesson Feedback

Comparing Lee, Lim and Kim (2017)'s model to the other design models in the five works so far discussed in this section, the model of Lee, Lim and Kim is a detailed description of what is involved at each design stage of the design process. They present the final design model unlike the works of the other researchers. Aşıksoy & Özdamlı (2016) could only show how they integrated the theoretical framework for designing the FCA but did not focus on the design aspects that could help other practitioners to develop their own model for teaching. Though they did not explicitly articulate the key principles to guide the same design for others interested in coming up with their own models, the final product itself may serve as a useful guide to such an end. Lo and Hew (2017) did not come up with design principles, nor a final articulated model of their design, but the way they incorporated Merrill's (2002)'s principles tend to provide meaningful guidance on how to structure an FCA model for a particular course design. Their work shows a simplified but effective way of designing an FCA model using Merrill's principles, specifically when it comes to applying the principles to the in-class and out of class phases of the FCA. On the other hand, Kim, Kim, Khera and Getman (2014) do not also provide a final artefact that shows how activities can be designed and integrated within the two phases of FCA, but they provide a set of principles for one to design his / her won.

Together, these studies provide important insights into how FCA may be used to design a course. Each of the models studied, when examined carefully, has tenets that can be incorporated together with the other models to produce a final meaningful product of a course design that uses FCA. For example, Fink's model used by Martinez, Lombaerts and Celeya (2017) is a powerful model that shows key elements that need consideration when designing course instruction, such as learning goals, the teaching and learning activities, and feedback and assessment. The same applies to Merrill' principles applied by Lo and Hew (2017), as the principles are a powerful guide to what should actually be done during each of the two phases of FCA instruction in a course design (activation, demonstration, application and integration). On the other hand, Aşıksoy and Özdamlı (2016) and Lee, Lim, and Kim (2017) may provide knowledge on how to structure the actual final artefact for the implementation of the course since these authors have attempted show how the final course design should look like, especially Lee, Lim, and Kim (2017) who show what is involved at each of the design stages of the final artefact. The final contribution from Kim, Kim, Khera and Getman can then be used by others as a generic guide for designing FCA instruction since it avails a set of propositions for guiding the design for an FCA instruction that considers other course components.

2.4.5 The use of FCA in higher education

The use of FCA in different subject areas in higher education and in different countries is on the rise. O'Flaherty & Phillips (2015) conducted a scoping review on FCA in Australia in which they examined literature on FCA from 2000 to 2014. They investigated how the key aspects that influence the effectiveness of FCA- design and conceptual framework of FCA; type and use of specific technologies to engage students; economic and time constraints required to implement FCA and pedagogical acceptance by students and teachers, contribute to student learning experience. A broad range of study designs were selected from eight electronic databases, leading to 28 articles being selected for analysis. Their review found out five key issues from the literature at that time, that:

1. Technologically the literature suggested a wide array of methods or tools that students can use in a reflective manner and self-paced manner for pre-class preparation, and were believed to improve student learning, specifically by enhancing class preparation, increasing classroom interactivity, and improving academic performance. These methods included pre-recorded lectures in the form of podcasts / vodcasts, screencasts, annotated notes, captured videos, the use of pre-readings, automated tutoring systems and study guides, interactive videos from an online repository (e.g., the Khan Academy suite of resources), case-based presentations and simulations. However, the authors found little validation to the effect that these methods could improve student learning.
2. Synchronisation of activities-there was need for instructors to redesign their curriculum in such a way that pre-class activities could be better integrated into the F2F (face to face) classes where active learning pedagogies (such as- case-based presentations, team-based

discussions, panel discussions, expert led discussions, role-plays and student presentations, discussions, and debates, complimented by micro lectures to support knowledge gaps) must be allowed to take place. Proper integration of pre-class activities into in-class activities can result in student understanding what the FCA model is about thereby motivating them to prepare for classes.

3. Time, cost and staffing for a flipped class- there was little acknowledgement of the intensity and effort required to develop interactive materials by higher education institutions, which may lead to little allocation of resources such as IT support, supervision that may be needed during F2F classes real time, or the funding need to acquire pre-class resources.
4. Pedagogical acceptance by staff and students- instructors do not have the capacity to design and evaluate the effectiveness of their flipped classroom. This becomes an obstacle towards acceptance of the flipped classroom pedagogy. On the other hand, the lecture method is familiar and comfortable, it becomes most preferable to both the instructor and students as it is instructor centred and requires little active student participation.
5. Evaluating short-term and long-term student learning outcomes- among the entire collection of articles reviewed, student learning particularly of higher order thinking cognitive skills (problem solving, inquiry, critical/creative) were not evaluated using a robust scientific approach. There was little evidence also on long-term improved educational outcomes of flipped vs traditional delivery approach.

These authors also found that most of the publications in flipped classroom instruction were in the United States (23 articles), and the remaining few from 4 other countries. The subject distribution was concentrated in health sciences (14 articles), while the remaining articles were published in other subject: languages, engineering, chemistry, commercials, sociology, research methods and information systems. Most of the studies compared the traditional approach with FCA in their designs approach and used mostly surveys with Likert scale and free response questions for data collection. Among other findings, mostly outstanding were student satisfaction and improved academic achievement.

Lundin et al. (2018) investigated the status of research on FCA with the aim of identifying and describing the challenges related to the study of FCA within the education sector. The study was conducted based on Scopus database of 530 most cited peer-reviewed academic articles between 2000 and mid-June 2016. Disregarding the quality of the articles, they reasoned that the more an article is cited the greater the social impact it had. Their review revealed a reasonable growth of publications in higher education, from 38% in 2012 to 73% in 2015. Out of the 47 countries whose articles were sourced from the database, 8 countries that featured at the top of the hierarchy in terms of flipped classroom research in higher education were, United States with the highest number of publications (321), followed by Australia (31), China (26), Canada (17), United Kingdom (16), Germany (14), Taiwan (14) and Italy (10). The publications were most in social sciences, computer sciences, engineering, medicine, and mathematics, respectively. However, it should be noted that these results were only from a single database within a specified period (2012-2015), which might not be the case if otherwise. Of all the studies published in this review, only one study by Kim, Kim, Khera, Getman (2014) proposed in detail nine design principles that may be used to design FCA, based on the design framework that emerged from the data collected by those authors. The authors used a mixed method design that included a survey, interview, and instructor reflection, with a sample of 115 student participants in an attempt to provide robust evidence or carry out a rigorous study that could reveal the potential of FCA. The rest of the other articles in their collection fail to provide information that may guide others who may want to design their own FCA in their subject areas. They simply talk about the methods used to collect the data, student achievement and student opinions, without describing the essential key components that made up their instructional designs of their interventions. From this review, FCA is mostly studied in higher education within the social science subjects, but there is a lack of information about the design principles of it that could be used to assist others who may be interested in implementing FCA in their own fields of study.

Uzunboylu & Karagözlü, (2017) studied the emerging trend of FCA in a period of 5 years from 2010 to 2015. They used Science direct database to retrieve 242 published articles from 17 countries and examined them. The selection criteria of the articles were based on the method used in the studies of Keser et. al. (2011), Ozcinar (2009) and Drysdale et. al. (2013). Their focus was on year of publication, country where the research was implemented, sample group, research method, subject area, research model, and data collection tools. The analysis of the compiled articles revealed that the most outstanding publisher of FCA was United States with 163 articles, followed by Malaysia and Jamaica each with 10 publications. Of the sample participant groups studied, the highest number (119) was undergraduate students while other sample groups (such as teachers, secondary school students, among others) had numbers between 8 and 21. The review findings showed all three main research approaches, qualitative, quantitative, and mixed method were used in the articles selected, with the most preferred being qualitative approach, followed by quantitative. In this review of Uzunboylu & Karagözlü, (2017), most of the flipped classroom studies were conducted in medical education (68 articles), while the rest of other subject areas had articles ranging between 3 and 21. A total of 18 subjects were the focus of all articles reviewed in this investigation. There were five outstanding research designs that were commonly used in these articles when studying FCA, namely experimental, case study, descriptive, review, and design based. The most preferred design was experimental (73 articles) followed by case study (72 articles). In all of the articles that were reviewed by Uzunboylu & Karagözlü, the most frequently used data collection method was the survey (47 articles), followed by achievement tests (43 articles). Uzunboylu & Karagözlü (2017) results and those of O'Flaherty & Phillips (2015) complement each other in asserting United States as the major researcher in FCA in higher education, and medical education being the mostly highly researched area in higher education.

Four outstanding things can be seen from the three reviews: (1) all three reviews agree that United States is in the lead in studying FCA, (2) most of the studies in FCA are in higher education, and are on the increase, (3) majority of these studies are in the health sciences, social sciences, and STEM (science, technology, engineering, and mathematics) subjects, and (4) though many researches are being conducted on FCA, O'Flaherty & Phillips seems to be the only authors up to the time of their study who attempted to report on how to use the results of a study to develop design principles for flipped classroom instruction to help instructors effectively engage with students particularly when dealing with higher order thinking cognitive skills. The design and implementation of an instructional intervention are the crucial components to effectively achieve any learning goals. O'Flaherty and Phillips (2015, pp. 85-95), pointed out six issues that need to be addressed by literature for effective flipped classroom implementation, if at all curriculum transformation by educators is to take place:

- *The under-utilisation of conceptual frameworks that enable a united approach to pre-, F2F and post-learning activities, resulting in a lack of clarity and heavy content focus.*
- *An under-developed capacity to blueprint, that is, to translate conceptual frameworks into context-specific plans*
- *The lack of understanding of how to design and support inquiry-based learning and metacognition in a flipped learning curriculum.*
- *The need for stronger evidence in evaluating student learning outcomes that particularly improved student learning and development, as critical thinkers, problem solvers and team players*

- *The need to stimulate higher order thinking using creative technologies and applied learning*
- *The need for guidelines about current approaches to assessment and feedback, e.g., writing quality learning checkpoints (in pre- and/or F2F sessions).*

This study considered the six issues indicated above, as part of its guiding theoretical framework for the design of the intervention produced in this study. The six issues helped identify essential elements incorporated in structuring both the initial and final draft interventions. The first point on the list suggested the need for a design theory or principles that harmonises all three phases of the FCA framework: i.e., -before class, during class and after class phases. The second point on the list helped to focus on the importance of translating the literature-based design principles into specific plans that produced the actual instructional intervention. The third point on the list was necessary to describe how these six key ideas could made to work together to produce a learning experience or environment where students were able to actively engage in activities that encouraged them to interrogate the content they were studying, and furthermore, to be intrinsically motivated to work on their own on any problem to which they were exposed. The fourth point was taken as a guide on how assessments and evaluations could be done so that students' knowledge and understanding of the content would grow through feedback and self-reflections. In addition, the idea also hinted on encouraging students to work collectively as a community with a common purpose. This was to help them gain confidence in themselves and develop critical thinking abilities as they worked on tasks provided by the instructor. The fifth point taken as an element that informed the nature of the tasks needed to challenge the mental abilities of the students. The last point informed the study on the need to use different methods of assessments currently available to ensure each of the three phases of FCA was effectively implemented. Activity theory (AT) was considered as the most appropriate theoretical framework that could guide how the entire study could be conducted. Details of how the framework was used are discussed in section 2.5.

2.5 THEORETICAL UNDERPINNINGS OF THE STUDY

2.5.1 Background of theory employed

This study was informed by Activity Theory (AT), originally termed Cultural-Historical Activity Theory (CHAT) by Vygotsky (Wilson, 2006). AT is a theory that originated from the Soviet Union by Lev Vygotsky, Luria and Leontev, and was further developed by Engeström (Kuutti, 1996;

Barab, Evans & Baek, 2004; Gedera, & Williams, 2015), as an alternative to Western theory of behaviourism in psychology. Unlike the theory of behaviourism that tended to limit research studies to experimental laboratory environments, AT was developed as an attempt to create research that involved humanity and its environment, thereby allowing studies to incorporate the context of human lives. AT is based on the materialistic philosophy of Marxism which assumes human beings live in objective reality, where objective reality determines and shapes how people think (Kaptelinin, Kuutti, & Bannon, 1995, July). As such, AT offers analytical and conceptual tools to examine human practices (Gedera, & Williams, 2015).

2.5.2 AT as theoretical framework

Kuutti (1996, p. 532) defines AT through a broad definition as "a philosophical framework for studying different forms of human praxis as developmental processes, both individual and social levels interlinked at the same time". In other words, the theory is a perspective that considers human activity as a process that simultaneously develops both the individual and the social group, he/she belongs to. Human praxis is an activity that enable people to acquire knowledge and skills, and transforms their social conditions, resolve contradictions, generate new cultural artifacts, and create new forms of life and the self (Sannino, Daniels & Guitierrez, 2009). Jonassen and Rohrer-Murphy (1999, pp. 64-68) highlighted the following assumptions of AT as crucial when using it as analytical framework in a study:

1. *Unity of consciousness and activity*- "Conscious learning emerges from activity, not as a precursor to it" (Jonassen and Rohrer-Murphy, 1999, p. 62). In this case, activity is understood to mean human interactions with the physical or nonphysical world (i.e., real life situations). Learning does not take place before acting but emerges when people are interacting with (or acting on) the environment. Knowledge is a part and parcel product of the interaction between people and the environment. Activity comes first before a person can learn something. The activity may be sensory (action involving the 5 senses), mental (requiring thinking or anything that stimulates, activates, or enriches the mind) or physical (requiring bodily movement). In addition to the fact that activity is a precursor to knowledge, the relationship between consciousness and activity is also dialectical in nature. "Not only do activity and consciousness coexist, but they are also mutually supportive" (p. 65), meaning the relationship between knowledge and activity is reciprocal. As people act, they gain knowledge about their environment, and in turn the knowledge acquired affects how the same people act towards that environment. Thus, our actions towards something changes our knowledge and vice versa.

2. *Consciousness is manifested in practice*- knowledge in humans is revealed through action. Knowledge embodies attention, intention, memory, reasoning, and speech (language) as one entity. Human activity leads to knowledge gain and takes place within social groups involving people and artefacts (i.e., physical or symbols/sign systems). As such, activities must be analysed taking cognisance of the nature of the activity, since goals, needs, beliefs of the people associated with it, and the artefacts used in it will determine how it is carried out. Thus, an individual's own act to gain knowledge takes place within a bigger system involving other people and artefacts of use. This knowledge, internalised as changes in physical, mental, or social conditions, is reflected through the individual's conscious actions.

3. *Intentionality*- an activity is initiated by an intention (motive). Humans interact with and learn about their environment to fulfil their needs. Needs arise from contradictions that individuals experience in their environment. For an example a contradiction may arise because of lack of knowledge between what people need to know to accomplish a goal and what they are doing. In such a situation an intention emerges, and people act intentionally to address the need. Intentions are always linked to a particular activity. Actions are then intentionally planned with goal(s) in mind. The plans and goals may change depending on what is needed to be known at a particular point in time.

   Taking an example of learning as an activity, for students, the learning process is always directed towards acquisition of specific types of knowledge. Knowledge acquisition (an object of study) is the intention or motive that satisfies the student's need for learning. It should therefore be understood that an activity is undertaken to meet a particular need. When students have some other need other than the acquisition of knowledge, learning is no longer an activity but an intermediary objective (Talyzina, 1981). It simply becomes some action of another activity. Knowledge acquired during this learning process will not serve as motivation, but an action objective since it does not activate the learning process.

4. *Object-orientedness*- intentions are directed at objects of activity. Anything that can be transformed by the actors in an activity is referred to as an object, such as the written objectives in instructional design. They may be physical, soft (computer programme), or conceptual (theory or model). Transformation of an object gives out an outcome. Thus,

motivation in an activity comes from the transformation of the object/goals. Object of the activity are therefore the intended actions in an activity. The type of activity is identified by the nature of the object.

5. *Community as a dialectic context*- activities are contextually bound, meaning they can only be described within the context of the community in which the activity is practiced. The community dictates the rules and customs of how its members operate or behave, its beliefs, and how different activities must be carried out. Roles are allocated to members of the community as division of labour with rules enforced for the activities to successful. Rules and customs of different communities are not the same, and so beliefs of each community are continually changed to accommodate other groups in a relationship of mutual benefit. Conflicts can arise between roles in different communities leading the need to transform activities to harmonise the contradicting expectations.

6. *Historical –cultural dimension*- activities do not just appear but develop from the past and evolve over time within a cultural group to the status where they are. This proposition demands that for any given situation, we examine the changes that took place over time to understand its dynamics. For an example, to understand why new instructional designs incorporate new technologies requires us to look back into the past on how instruction was designed and how that evolved with time and knowledge shared within the instructional community.

The social and cultural context character tells us that the process of knowledge acquisition in people takes place within the context of human relationships. The interaction between mind and activity takes place within relevant environmental contexts. According to (Dudley-Marling, 2012, p.3095), "context affects how people learn…what is learned…and is itself part of what is learned". Thus, the socio-cultural environment plays an important role in developing knowledge through activities. The social and historical character requires us to understand "all human learning as occurring within particular cultures, with particular histories" (Randles & Pasiali, 2012, p. 719). Human praxis is a shared activity among members of a community of practice, who have a particular culture or a way of doing things that has developed over time. This character differentiates AT from behaviourist and constructionist theories which respectively consider learning as being centered on the solitary actions of individuals, and "on the interaction between the individual and his or her environment" (p. 719).

7. *Tool mediation*- an activity involves use of artefacts, whose role must be understood particularly when they are integrated in social practice. Artefacts considered to be instruments, signs & symbols, procedures, machines, methods, and forms of work organisations. Development of knowledge in people is achieved when tools alter the nature of human activity and the changes that occur are internalised. It is therefore necessary to comprehend the nature of tools that mediate our work by examining the way people use them, the needs they deserve, and the history of their development. Tools are also changed by the way they are used. They change over time through processes in which they are involved, and the processes are also changed by tolls over time.

8. *Collaboration*- an activity is a system of collaborative human practice. An individual's ability to perform is based on collaboration of other groups of people. Very little meaningful activity can be accomplished individually - meaning any human activity considered individual, is part of social relations, because activities are complex processes necessitating collaborative effort.

The central concept in AT is the activity system. An activity system is "the basic unit of analysis of behaviour, individual and collective" (Russell, 1997, p. 510). According to Russell, (1997, p. 510), "an activity system is any ongoing, object-directed, historically-conditioned, dialectically-structured, tool-mediated human interaction". Kain & Wardle, (2014) explain the key elements in this definition namely and as follows- *ongoing*- implying looking at how the system functions over time, how it began in the past and how it might evolve in the future. *Object-oriented*- activities are directed towards specific goals. *Historically conditioned*- implying there is need to consider how a system came to function in a particular way. Systems come into being because of practices that have a history. *Dialectically-structured*- where aspects of a process or system are considered to have a relationship that is mutually dependent. Implying a change in one aspect triggers change in other aspects in response. *Tool-mediated*- activities are accomplished by use of tools which may be physical tools (computers, textbooks, syllabi, lab equipment, etc.) or systems of symbols (e.g., in mathematics and physics). The nature of tools used to accomplish the goals of learning mediate or shape the way people engage in activities and the way people think about the activity. *Human interaction*- activity systems are not about separate actions of individuals, but about how people

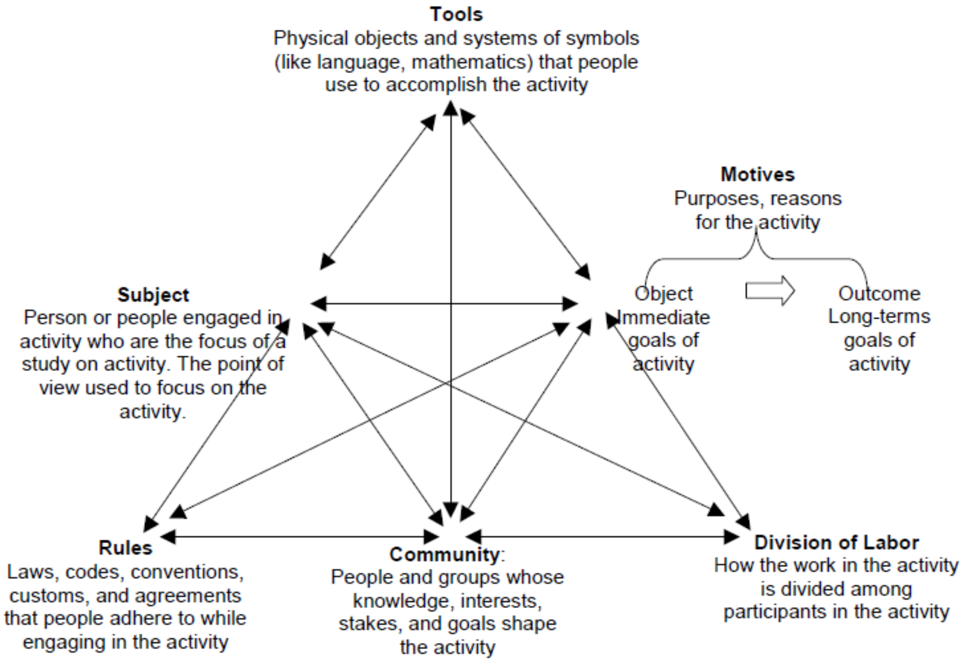


Figure 2. 7: Activity system (Kain, & Wardle, 2014, p. 3)

work together, using tools, toward outcomes. Activity systems are constrained by divisions of labour and rules.

According to Jonassen and Rohrer-Murphy, (1999):

> *"An activity cannot be understood or analysed outside the context in which it occurs. So, when analysing human activity, we must examine not only the kinds of activities that people engage in but also who is engaging in that activity, what their goals and intentions are, what objects or products result from the activity, the rules and norms that circumscribe that activity, and the larger community in which the activity occurs" (p.62).*

Jonassen and Rohrere-Murphy through their statement above, are pointing out the critical elements in an activity system that must be examined. These elements are represented in figure 2.7, where the arrows indicate reciprocal relationships among these various components of the activity system.

According to Wilson (2006) and Kain, & Wardle (2014), the components may be interpreted in the following way: the *subject(s)* is/are the person or group of persons who are directly participating in the activity under study, where the analysis of the activity is based on the point of view of the person(s) participating in the activity (Demiraslan & Usluel, 2008). The *object* of the study is immediate and is that which is acted upon by the subject in ways directed by a predetermined goal. In view of Demiraslan & Usluel, the object is the target of the subject, community, or the activity, within the system. Wilson (2006), as well as Kain and Wardle (2014) describe *Motives* as desired intentions which may be *goals* (as object of activity) or *outcomes*. Motives direct the activities of the subject. An activity can be broken down and organised according to the following hierarch: *activity*, *action*, and *operations*. Figure 2.8 is a graphical representation of this hierarch, and how the structure is related to motives, goals, and conditions under which the activity is carried out. An activity is undertaken to fulfil a motive.

An activity is performed through actions. An action is undertaken to fulfil a goal. An action is implemented through an operation. An operation can only be undertaken if it fulfils certain conditions. The structure shows the hierarchal nature of an activity when broken down into its constituent levels, with the activity at the top and operations at the bottom.

The motive drives the whole activity while conditions at the bottom determine whether the activity can be started or not. The *action* is the level when people learn to use a tool and takes place consciously. They can think about how to use the tool productively. Over a period, they no longer need to think about how to use the tool but can perform the action unconsciously. The action is now operationalised and happens automatically. However, an operation can still transform back to action if it is left undone over a long period of time as one forgets. Thus, an activity comprises of sets of actions directed towards accomplishing specific goals, and operations. Actions only have meaning when they are part of an activity, such as driving to work is an action that only has meaning when there is work activity (Crawford & Hasan, 2006).

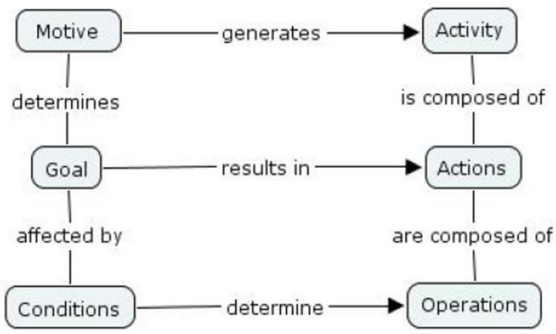


Figure 2. 8: Relationship between- activity, actions, and operations (Wilson, 2006, p. 8)

The *tools* are the items used by the subject(s) to accomplish what they want to achieve (the object/objectives) during the activity. Tools mediate the activity system and can either be artefact

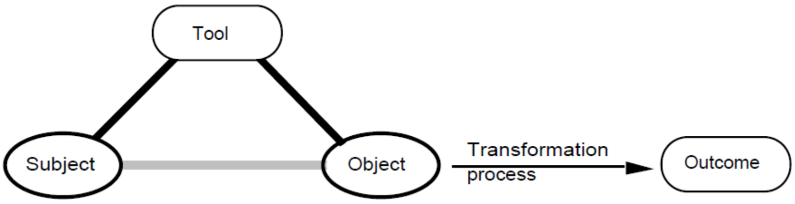


Figure 2. 9: The triadic relationship (Kuutti, 1996, p. 8).

(physical material) or non-physical (abstract) in nature (e.g., language and skills). The social basis of the activity system comprises of *rules*, *Community*, and *Division of labour* (Engestrom, 1999).

According to Demiraslan and Usluel (2008), external (physical) or internal mediating (psychological) artefacts which help in achieving the outcome are *tools* of the activity system. Within the activity system, actions, and interactions between the components of the system are constrained by *rules*, which are regulations, norms, and conventions of the activity system. They emanate from the community and or the broader cultural context in which the interactions take place. How tasks are divided within participants or community members of the activity system is referred to as *division of labour*. The division may be vertical or horizontal, meaning may be among people of the same rank, or different ranks.

The main feature of AT revolves around the triadic relationship between the object of cognition, the active subject, and the tool or instrument that mediates the interaction between the subject and object elements represented in figure (2.9) below:

Figure 2.10 with bi-directional arrows shows that "in the heart of the activity system, learning occurs through a dialectic or transactional interaction between subject, community and object" (Hung, & Wong, 2000, p. 34). Thus, the circle at the heart of the triangle is indicative of the social negotiation of knowledge. The social basis of the activity system, which comprises of rules, community, and division of labour, tells us that the subject-community relationship is mediated by rules, while the community-object relationship is mediated by division of labour. Rules govern how the subject(s) and community work together, while division of labour dictates responsibilities among community members.

2.5.3 Relevance of AT to the study

Foot (2014) argues that if scholar-practitioners are to advance their ways of thinking about shaping their professional practices, they need to use AT as a tool for both structuring the entire research activity, and analysis of its data. Foot further exemplifies this argument by citing a case such as development of a curricular and teaching at all educational levels. This argument is better explained by Kaptelinin and Nardi (2012) who described contradictions that exist in an activity system as forces of development. In this study, the contradictions show how relevant AT was to the study.

AT describes an activity as a process in which all its elements, (see Figure 2.7 and Figure 2. 10) interact with each other. The activity itself is an organisation of other sub-activities but all purposed to produce a joint outcome. In this study, the activity process was the FCA as an instructional process meant to develop a greater understanding of geometrical optics subject matter knowledge (SMK) in pre-service teachers. The components of the activity system were: students, as the subject of the activity and whose views of their learning experience based on FCA were analysed; the learning materials and management systems employed during the study, as tools

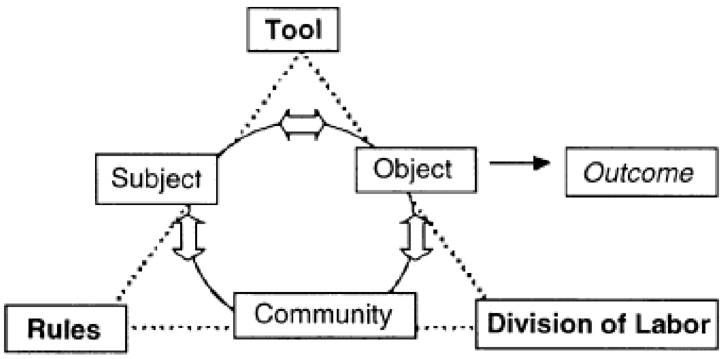


Figure 2. 10: Basic structure of an activity system (Hung, & Wong, 2000, P. 34).

mediating the activity; the targeted content objectives as the object of the activity; the regulations governing the conduct of each activity in which students were involved, such as behaviour in the class, how assessments were to be conducted, class attendance, consultations requirements, laboratory requirements, regulations governing communication among participants- including the instructor, departmental regulations, university regulations, among others- as rules of the activity system; the community of significant others-such as the students themselves as a community of learners, the instructor, other departmental staff members and students in the same department as well as others in the same school of education; and division of labour associated with who does what among students when given tasks to solve collectively, the role of the instructor, and the roles of other within the community outlined. Thus, the AT helped identify essential elements of the FCA activity system and the role they played in meeting the target of the activity system.

As pointed in the first paragraph of this section, Kaptelinin and Nardi (2012) identified four types of contradictions of AT that make the theoretical framework very relevant to the study, especially when it comes to the analysis of results. These contradictions, and their relevance to the study are described in the paragraphs that follow.

The first type of contradictions are those referred to as inner contradictions. These are challenges or problems that exist within each element (tools, object/outcome, subject, etc). An example might be an unexpected outcome when the subject acts on the object-i.e., when students are solving tasks associated with specific learning goals, or problematic characters in terms of students when conducting a lesson, among others. When alternative decisions are made to overcome the challenges, this will be due to contradictions. Thus, contradictions affect the role played by each component in the activity taking place and lead to new ways of thinking to address the challenge, thereby developing the instructional approach and new knowledge on how to solve certain type of problems becoming available.

The second type of contradictions that need analysis are those between components/elements of the activity system. The relation between components is dialectic. A change in one component tends to affect the other component. An example may contradictions between tools and goals of instruction. There might be problems associated with alignment of instructional strategy (conceptual tools) objectives (the object) leading to unintended outcomes. A change in goals should go hand in hand with teaching strategies appropriate enough to achieve that goal. Thus, views of participants related to such relationships need to be considered and new ways proposed.

The third type of contradictions are those that may exist between the current status of an activity, and the potential future status of the activity. One such an example may be resistance to change by students when a new instructional approach is introduced. Views of the subjects (students) need to be analysed in this regard to address the causes of such resistance. From such negative perceptions lessons are learnt from reasons behind them.

Finally, the fourth type of contradiction is those existing between networks of activities. As indicated earlier on in this section, an activity comprises of other smaller activities, but all involved in a joint outcome. As an example, there might be a positive effect on a goal due to a particular activity conducted, but there might be an improper follow-up activity to ensure the results do not change. Another example may a positive effect on a study activity but improper assessment activity. Student views on such activities may then be analysed to improve the instructional strategy.

Thus, AT becomes an analytical tool very relevant in identifying flows in an activity system. These flows are lessons that are learnt to avoid same problems in future of similar activities. The flows help define principles that can guide future design of other activities.

2.6 SUMMARY OF THE CHAPTER 2

This chapter began by providing an overview of the four main themes that constitute it. It was necessary to provide a background of what a course design entailed since it was one of the main concepts mentioned in the topic. Course design was understood to consider instructional goals, subject matter content, instructional strategies and assessment and evaluation, as its key components. Ideas that were investigated that could inform the design of a geometrical optics course, as pointed out in the title, were expected to address these aspects.

It was also necessary to describe the content and misconceptions about geometrical optics. The intention was to provide an understanding about the background related to the type and nature of content the participants were dealing with, as the knowledge was considered helpful for the reader to understand the instructional approach employed in the study.

The discussions went on to examine FCA in terms of its definition, its developmental history, its place as an instructional approach, sample models and its use in higher education. This background was meant to provide an understanding that FCA was an instructional strategy with certain origins, but still developing and why today it is necessary to pay attention to it.

The last issue to be looked at was the AT, taken as the framework of the study, because of its potential to be used as an analytical tool. It was used to examine the entire instructional activity, as well as for the analysis of data obtained from the participants. The next chapter discusses the methodological process that was employed in this study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The purpose of this study was to design and implement an intervention for teaching geometrical optics based on flipped classroom approach framework. To accomplish this purpose, the study was guided by the following research questions:

1. What components of a flipped classroom are appropriate for designing a geometrical optics course in physics?
2. How do components of a flipped classroom approach inform the design of a geometrical optics course in physics?
3. What is the effect of the intervention on students' performance in geometrical optics in physics?

This chapter has been divided into various sections which describe the different stages of the research process. After the introduction which restates the research questions, the research design (see section 3.2). This section provides the philosophical underpinnings of the study, mixed methods research design, and a detailed description of design-based research (DBR) as the methodological framework employed to guide the collection of data and how it relates to the mixed methods approach. Within this section, discussion is also provided on the three phases of the intervention design-the Preliminary research, Prototyping phase, and the Assessment phase. This is where details are given on how the study was divided into micro studies, and how data was collected from each micro study. The third section discusses the instruments employed during the entire study. Details of instruments or tools used to collect the data, validity and reliability of these instruments, data collection methods, as well as data analysis are provided in order to give a clear picture of how the data collection process unfolded. The fourth section (3.4) discusses ethical considerations. The section discusses participant safety, as well as the guaranteed anonymity. The last section provides the summary of the chapter (see section 3.5).

3.2 RESEARCH DESIGN

According to Asenahabi, (2019), research design entails providing a planned procedure on how to collect and analyse the information needed to answer the research questions. Research design helps identify the type of data required, the methods for collecting and analysing the data, as well as how the research question will be answered. It guides the researcher to the kind of analysis needed to obtain the desired research results. The researcher must have knowledge of methods and techniques and how to use them. There are three types of research designs from which a researcher can choose from, quantitative, qualitative, and mixed methods (Creswell, 2014). A quantitative design leads to measurement associated with the production of quantifiable data. A qualitative design requires the researcher to explore and understand the meaning attached to a social or human problem by a person or group of people. The mixed methods research design incorporates both elements of quantitative and qualitative design, with the purpose of getting a greater understanding of the problem. The choice of a research design is usually guided by the philosophical underpinnings of the study.

3.2.1 Philosophical background of the study

In this section, it is important to establish first the philosophical background or paradigm on which the study is anchored, since the philosophical background determines the methodology used to collect relevant data to answer the research question. A philosophical stance or paradigm is a belief system, or a set of beliefs (or world view) that guides the action taken by a researcher studying a phenomenon, or a social problem (Bhattacherjee, 2012; Creswell, 2014). Researchers tend to view problems about a social reality in different ways, such that their thinking and reasoning about how to address the problem are constrained by these beliefs. The way researchers think and reason, when conducting a study tend to reflect the characteristics of the paradigm to which they belong. Researchers address three basic questions which are ontological, epistemological, and methodological in nature during a study. The way they respond to these three questions characterises the paradigm they chose to guide their study.

According to Bhattacherjee (2012), a paradigm has two sets of assumptions: Ontological and Epistemological assumptions. Ontology is about how the world is constituted (i.e., does the world consist mostly of social order or constant change), while epistemology is about how this world can best be studied. A researcher's paradigm therefore determines (i) how he or she perceives the surrounding world and (ii) how he or she gets to know about that same world.

There are different paradigms or philosophical perspectives which are at the disposal of a researcher when undertaking a research study. An example of such paradigms include positivism, constructivism, pragmatism, or critical theory, just to name a few among others. Table 3.1 shows these paradigms and their related assumptions (i.e., ontological, epistemological, and methodological assumptions). For each of these philosophical perspectives, ontology is the starting point that informs epistemology. Epistemology in turn informs methodology, while methods are informed by methodology. Thus, a paradigm is characterised by ontology, epistemology, methodology and methods (Bowen, 2008; Lincoln, Lynham, & Guba, 2011; Creswell, 2014; Kivunja, & Kuyini, 2017).

Table3. 1: Different philosophical perspectives

Research Paradigm	**Ontological Perspective**	**Epistemological perspective**	**Methodological perspective**
Positivism (objectivism/realism)	*What is the nature of reality?*	*What is the relationship of the researcher to that being researched?*	*What is the process of research?*
	Reality is objective and singular, apart from the researcher	Reality can be measured and known. Researcher is independent from that being researched	Quantitative methods
Interpretivism (constructivism/naturalism /idealism/rationalism)	*What is the nature of reality?*	*What is the relationship of the researcher to that being researched?*	*What is the process of research?*
	There is no single Reality or truth/ There is multiple realities. Reality is subjective and multiple as seen by participants in a study.	Reality needs to be interpreted. Researcher interacts with that being researched.	Qualitative methods
Pragmatism (functionalism)	*What is the nature of reality?*	*What is the relationship of the researcher to that being researched?*	*What is the process of research?*
	Reality is constantly renegotiated, debated, interpreted	Best method to use is the one that solves the problem	Consider the practical effects of the objects of your conception

This study was guided by a pragmatic philosophy for the collection and examination of its data. Creswell (2014; pp.39 - 40) describes the main characteristics that distinguish pragmatism from other research paradigms:

- Pragmatism is not committed to any one system of philosophy and reality. This applies to mixed methods research in that inquirers draw liberally from both quantitative and qualitative assumptions when they engage in their research.
- Individual researchers have a freedom of choice. In this way, researchers are free to choose the methods, techniques, and procedures of research that best meet their needs and purposes.
- Pragmatists do not see the world as an absolute unity. In a similar way, mixed methods researchers look to many approaches for collecting and analysing data rather than subscribing to only one way (e.g., quantitative, or qualitative).
- Truth is what works at the time. It is not based in a duality between reality independent of the mind or within the mind. Thus, in mixed methods research, investigators use both quantitative and qualitative data because they work to provide the best understanding of a research problem.
- The pragmatist researchers look to the '*what* and *how'* to research based on the intended consequences—where they want to go with it. Mixed methods researchers need to establish a purpose for their mixing, a rationale for the reasons why quantitative and qualitative data need to be mixed in the first place.
- Pragmatists agree that research always occurs in social, historical, political, and other contexts. In this way, mixed methods studies may include a postmodern turn, a theoretical lens that is reflective of social justice and political aims.

- Pragmatists have believed in an external world independent of the mind as well as that lodged in the mind. But they believe that we need to stop asking questions about reality and the laws of nature.
- Thus, for the mixed methods researcher, pragmatism opens the door to multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analysis.

The characteristics of a pragmatic philosophy, as provided by Creswell (2014; pp.39 - 40), were used as the basis for choosing the research design for this study as mixed methods research design.

The mixed methods research design assumes that both quantitative and qualitative designs have their own weaknesses, which can only be strengthened by combining them (Asenahabi, 2019). Under mixed methods research design, collection of both quantitative and qualitative data may take place in three different ways or strategies. First - convergent parallel mixed methods- where both quantitative and qualitative data are collected at the same time, but analysed separately, with the sole purpose of finding out whether data from each type of design confirm the findings of the other (Caswell, 2014). Second – exploratory sequential mixed methods – in which views of participants are sought and data analysed. The information is then used to inform the quantitative phase that comes after. Third - explanatory sequential mixed methods- in which quantitative data is collected first and analysed, followed by collection of qualitative data and its analysis. The qualitative data is used to explain the quantitative data. According to Creswell (2014), the strategy involves using the results of the quantitative data to plan for the second phase of collecting qualitative data. In this study, explanatory sequential mixed methods strategy was employed.

3.2.2 Methodological framework

Design based research was used as the methodological framework for this study. Barab (2014) assets that DBR is for studying learning environments created by a researcher. The researcher can modify the environment to achieve specific goals. According to Barab (2014), DBR is not a method, but a general approach encompassing other research approaches. The activities studied by this approach are in a naturalistic environment or settings. The purpose for using this methodological framework is twofold, to generate theory, and to cause direct impact on practice, in ways that improve the outcome of the activity under study. DBR studies learning as it unfolds, by using innovative interventions which undergo multiple iterations. The intervention can be examined, and reasons for its success and failures provided at any of its iterative stages. Thus, by so doing, new theories, artefacts and practices are generated with possible use in other similar settings. During iterations, changes that influence learning and practice are examined. DBR therefore presents a methodological framework for advancing theory and practice.

By definition, according to Wang and Hannafin (2005), DBR is:

> *"A systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings and leading to contextually-sensitive design principles and theories"* (pp. 6-7)

According to Derry, Hackbarth and Puntambekar (2018; p.1), DBR refers to:

> *"a mixed methods approach that involves the iterative and systematic design, development and study of theoretically guided educational innovations in their implementation contexts".*

Wang and Hannafin in their definition of DBR acknowledge that DBR is a methodology with a specific purpose in education of designing learning environments and principles that guide how to construct them. However, Derry, Hackbarth, and Puntambekar go on further to point out that, even though DBR is a methodology on its own, when compared to the traditional quantitative and qualitative research approaches, it does not belong to either of the two but take the middle stance of the mixed methods research approach.

Mixed methods research is the joint use of quantitative and qualitative methodologies to optimise the advantages offered by either or minimise the impact of their limitations. The use of quantitative and qualitative methods as combined methodology has been employed in medicine since mid-19th century, and throughout the history of social sciences (Maxwell, 2016). Qualitative investigation was valued for playing the role of complementing statistical analysis. One of the valued strengths of the mixed methods methodology is its ability to integrate data from the two methodologies to develop conclusions at a depth much more than can be offered by each single entity.

It is not only in medicine or social sciences the integration of quantitative and qualitative approaches has been employed, but even in natural sciences such as geology, astronomy, biology, etc. (Maxwell, 2016). The studies show an inclusion of tables, graphs, among other quantitative data but with verbal descriptions (qualitative data) used to support the quantitative data in drawing conclusions. The inclusion of the qualitative aspect fits in well with interpretive inquiry in social sciences as pointed out by Smith (2008; p. 488):

> *"Interpretive inquiry, as is the case with all forms of qualitative inquiry, focuses on understanding (interpreting) the meanings, purposes, and intentions (interpretations) people give to their interactions with others".*

DBR, as pointed out earlier on by Maxwell, is an approach involving integration of both quantitative and qualitative methods and data, though it has received little recognition from the mixed methods community. In educational settings, it is used to improve educational interventions environments. DBR is a concept that originated with Brown (1992) and has a beginning in an experimental setting rather than one that is natural and leads to experimental work, though some may argue otherwise. The concept is adapted to a more naturalistic environment by implementing multiple iterations to a theoretically designed intervention. The intervention is continuously tested, refined, as well as assessed for its effectiveness and *how* and *why* it is so. DBR harnesses quantitative and qualitative strategies. There is experimental manipulation of the intervention, combined with qualitative data collection methods, where observation and interview techniques are used. The quantitative techniques more often involve pre-post testing and a Likert scale questionnaire.

The DBR approach exhibits typical natural sciences characteristics in that it alternates between observation and measurement and recording of both. Thus, fundamentally the approach aims to best describe specific and local features of the intervention and its outcomes, as well as the context in which these occur. Conclusions are informed by both quantitative and qualitative data. Data are closely integrated to develop and test the interpretation (theory) of what took place, as well as to generate fresh insights, new perspectives, and original understandings (Maxwell, 2016).

According to Bakker (2018), DBR is design research, and is neither methodology nor method, but something in between. It is more than an approach considering that research approaches or strategies such as survey, case study, or experiment can exist within DBR. Considering the contradiction between Wang and Hannafin (2005) and Derry, Hackbarth and Puntambekar (2018; p.1) in defining what DBR is, this study adopts the view taken by Bakker (2018) where DBR is understood to be a methodological framework since it tends to accommodate other research approaches within it, which is the case in the current study.

In this study, there was collaboration between the researcher and the participants, within a classroom setup, as an experimental setting rather than one that is natural. Thus, a mixed methods methodology in a DBR framework is employed and justified in this study.

The design adopted for this study was quantitative with qualitative validation (i.e., quantitative explanatory sequential design). More quantitative data was collected than the qualitative data, hence the qualitative data played a supportive role. The study was conducted in three distinct stages, in accordance with what Kennedy-Clark (2013) considers stages for conducting DBR. The first stage was the *preliminary research phase* involving context analysis and needs assessment, review of literature, and development of the original theoretical intervention. The second stage was the *prototyping phase* or iterative design phase involving four iterations of the originally designed intervention. Each iteration was regarded as a micro cycle or micro phase of the research, with mixed methods of data collection applied to improve understanding of the learning environment. The third and last stage was the *assessment phase* which was an evaluation of the extent to which the outcome of the study addressed the pre-determined objectives of the study, and the generation of recommendations for future work.

Figure 3.1 is an adaptation of Amiel and Reeves, (2008)'s DBR framework. It shows the overall structure of the design process. Both quantitative and qualitative data were collected during the prototyping phase. The quantitative data was examined using the correlational method since it is appropriate for analysing relationships between variables. A correlational method becomes useful when the intent is "to confirm or refute suspected relationships between or among the variables" (Tichapondwa, 2013, p. 119). The scores attained by the different groups of students

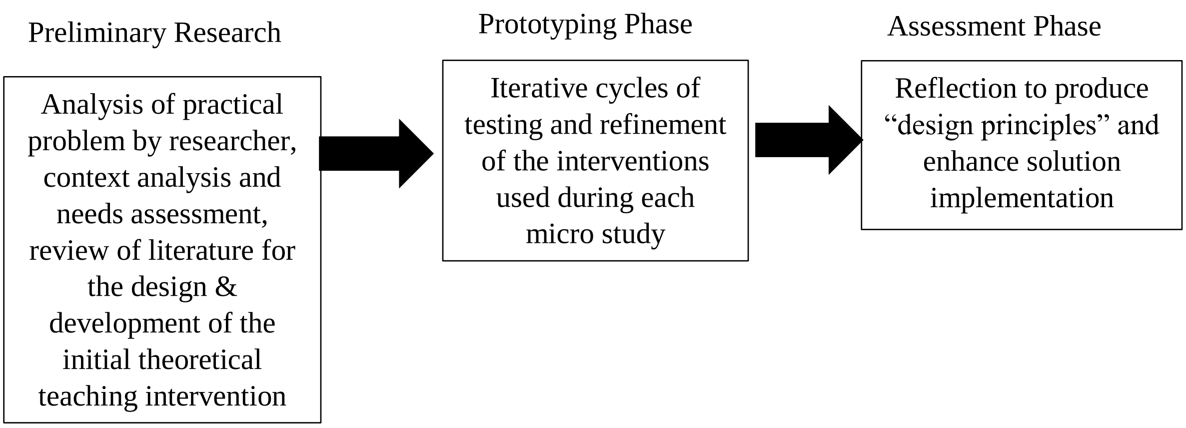


Figure 3. 1: Model of Design-Based Research (adapted from Amiel & Reeves, 2008)

at each micro study level were compared among themselves in an attempt to understand the relationships between them. On the other hand, the qualitative phase of the design took into consideration one of the key features of DBR, that it is used in real-world settings where such settings have many variables that can affect the outcome of the study, hence allows accommodation of the complex interactions and perspectives of the individuals in these settings.

As such, and also in accordance with AT principles, the opinions of the participants at each micro-study level were accommodated to form part of the qualitative data comprising of a multiplicity of viewpoints (Oberprieler and Leonard, 2015). Because the study involved use of data comprising of quantitative data involving correlational analysis supported by qualitative data, a quantitative correlational design with qualitative validation was found the most appropriate choice.

The data collection process and its analysis was conducted according to the four micro-studies shown in figure 3.2. The details of how each of these micro-studies was conducted is explained in the following section.

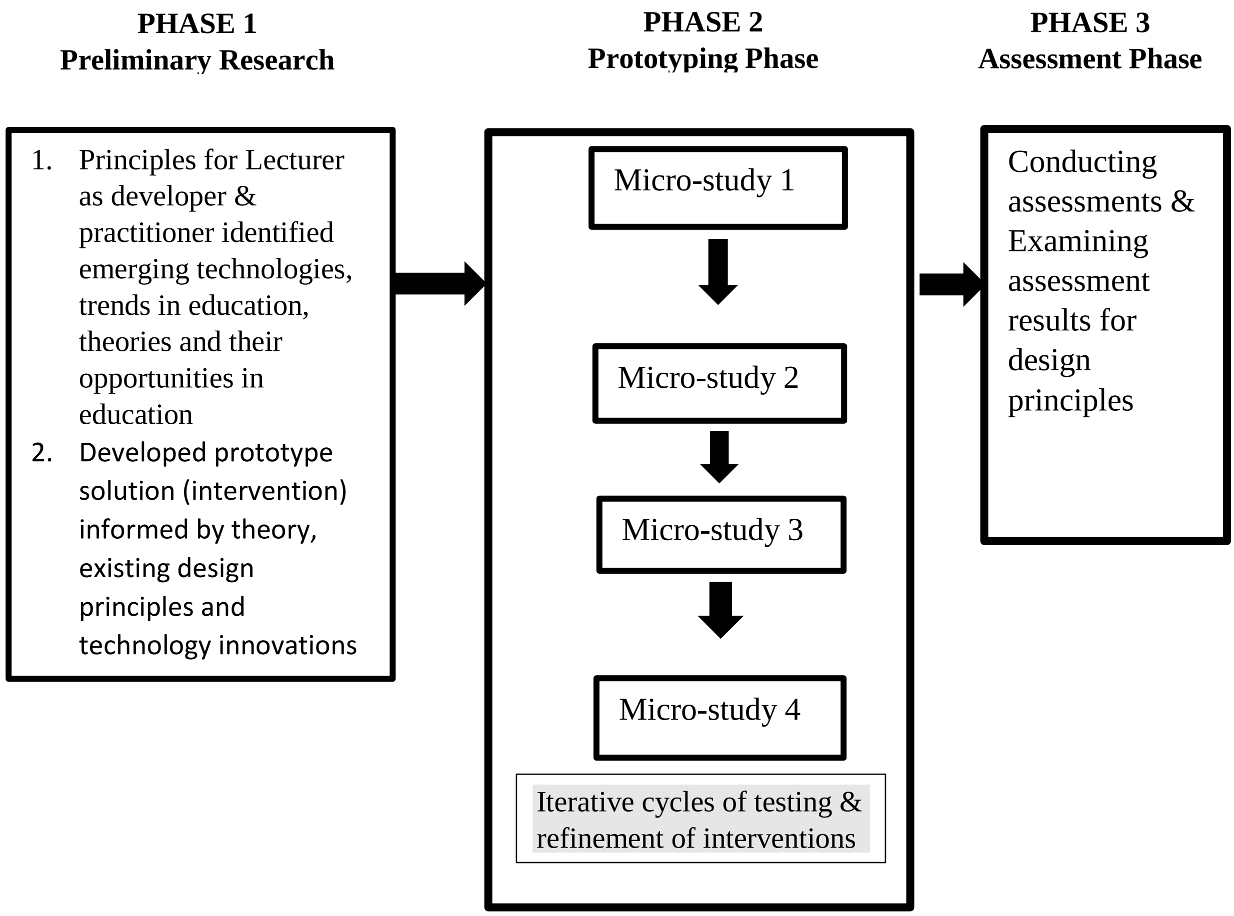


Figure 3. 2: Design and implementation phases of the study (adapted from Holotescu, 2015)

3.2.3. Phase 1: Preliminary research

Theory in design studies tends to guide thinking and locate existing design principles which may have been employed in similar contexts. It proposes how particular learning tasks or activities may be created (Herrington, Reeves, & Oliver, 2009). It therefore plays an advisory role in the design and development of interventions. Bearing this in mind, phase 1 in the design process was consulting the literature for principles that would guide the design, development and testing of the FCA-based intervention, as well as identifying the current technological tools that would facilitate the process of teaching and learning.

3.2.3.1. Principles for designing in- and out of class activities

The first set of principles from literature were based on constructivism theory of learning and were used to create a constructivist learning environment during the in-class and out of FCA phases. Thus, constructivist principles were used as a tool for designing the learning activities. These principles as provided by Herrington, Reeves, and Oliver (2009; p. 189) were:

1. Provide multiple representations of reality, which avoid oversimplification
2. Focus on knowledge construction, not reproduction
3. Present authentic tasks (contextualising rather than abstract instruction)
4. Provide real world, case-based learning environments rather than predetermined instructional sequences
5. Foster reflective practice
6. Enable context- and content-dependent knowledge construction
7. Support collaborative construction of knowledge through social negotiation, not competition.

These principles guided the design of activities and tasks intended for both conceptual understanding and application by students during the in-class and out of class phases of FCA. Technological affordances had also to be considered for the operationalisation of the intervention within the e-learning environment. According to the definition of FCA employed in this study (see section 2.4.2.), FCA was a technology based instructional approach. Thus, innovative technologies were to be part of the design solution of the problem being investigated. As such, an additional draft principle to factor in the technological character of the design is given below:

8. Consider technological affordances that are useful as cognitive tools, and for content delivery (such as computer programs (blackboard), websites, mobile technologies (smart phones), and collaborative tools such as WhatsApp.

According to Herrington, Reeves, & Oliver (2009), once the draft principles are identified, it becomes important to indicate how each of them will be represented in the learning environment. Thus table 3.2 illustrates the proposed role each principle was to play in the design of the intervention.

Table3. 2: Proposed role for each draft principle in the design of the intervention

Draft Principles		**Principle will be implemented in the learning environment by:**
1	Provide multiple representations of reality, which avoid oversimplification	Allowing students to present their views before class about the solutions of tasks worked out during class time
2	Focus on knowledge construction, not reproduction	Allowing students to explain their reasoning to questions and problems presented to them at any of the learning and assessment events
3	Present authentic tasks (contextualising rather than abstract instruction)	Exposing students to tasks that have contexts and to be interpreted according to contexts
4	Provide real world, case-based learning environments rather than predetermined instructional sequences	Design tasks/problems/activities for students that relate to their daily life experiences
5	Foster reflective practice	Affording students, the opportunity to provide feedback of the learning process, environment, assessments, communication, etc.
6	Enable context- and content-dependent knowledge construction	Affording students, the opportunity to solve content in context problems of higher cognitive demand individually
7	Support collaborative construction of knowledge through social negotiation, not competition	Permitting students to work in teams, solving problems in which individual members have their own share of the task assigned, and are expected to contribute meaningfully to the overall success of the group
8	*Technological affordances* • computer programs (blackboard) • websites • mobile technologies (smart phones) • collaborative tools such as WhatsApp	• Posting video lessons, and any other tasks, or communicating with students on blackboard • Instructor providing students with content specific websites • Encouraging students to use smart phones to access information posted on blackboard • Encouraging students to form WhatsApp learning groups to share information related to class activities

Merrill (2002)'s first principles of instruction were also used to guide the sequence of conducting in-class and out of class activities, and for organising the corresponding teaching and learning arrangements.

The principles of instruction define a problem-centered approach where direct instruction combines with the solving of problems rather than problem-based approaches "in which students are placed in collaborative groups, given resources and a problem, and left to construct their own solution for the problem" Merrill (2007; p. 5). Merrill (2002; pp. 44-45) proposed that: Learning is promoted when

1. Learners are engaged in solving real-world problems.
2. Existing knowledge is activated as a foundation for new knowledge
3. New knowledge is demonstrated to the learner.
4. New knowledge is applied by the learner.
5. New knowledge is integrated into the learner's world.

According to Lo & Hew (2017), Merrill's first principles provide a unique theoretical framework for implementing FCA as shown in figure 2.4. The first principle is situated at the centre to represent the problem being solved, while the outer four parts are the other four principles representing the sequence of instruction that must be followed to promote effective instruction. Combined with FCA, the principles are seen to be applicable during both the out of class sessions and the face-to-face class sessions. For making a video, the principles guided how the content included on the video should be structured, starting with activation, demonstration and ending up with application, though at the level of basic facts. The classroom situation is slightly different though. It starts with the principle of activation, then application, ending up with integration. The demonstration part is supposed to have been done already during the preparation period out of class. The roles of these principles at the time of implementing instruction are described in table 3.3 below.

Table3. 3: Principles of instruction and their roles during instruction (Merrill, 2006)

	Draft Principles	**Principle will be implemented in the learning environment by:**
1	Activation	• Learning is promoted when learners activate relevant cognitive structures by being directed to recall, describe, or demonstrate relevant prior knowledge or experience. • Activation is enhanced when learners recall or acquire a structure for organizing the new knowledge

2	Demonstration	• Learning is promoted when learners observe a demonstration of the skills to be learned that is consistent with the type of content being taught. • Demonstrations are enhanced when learners receive guidance that relates instances to generalities. • Demonstrations are enhanced when learners observe media that is relevant to the content
3	Application	• Learning is promoted when learners engage in application of their newly acquired knowledge or skill that is consistent with the type of content being taught. • Application is effective only when learners receive intrinsic or corrective feedback. • Application is enhanced when learners are coached and when this coaching is gradually withdrawn for each subsequent task.
4	Integration	• Learning is promoted when learners integrate their new knowledge into their everyday life by being directed to reflect-on, discuss, or defend their new knowledge or skill. • Integration is enhanced when learners create, invent, or **extrapolate** personal ways to use their new knowledge or skill to situations in their world • Integration is enhanced when learners publicly demonstrate their new knowledge or skill.
5	Task-centered	• Learning is promoted when learners are engaged in a task-centered approach which includes demonstration and application of component skills. • A task-centered approach is enhanced when learners undertake a progression of whole tasks

3.2.3.2. Design and development of initial intervention

The second stage under preliminary research which consisted of the development of a prototype solution informed by theory, existing design principles and technology innovations is presented in this section.

The design of the first prototype of the intervention followed a planning process and structure of McTighe & Wiggins, (2012), that guides curriculum, assessment, and instruction, known as Understanding by Design (UbD). It is a three-stage backward design process framework, where **stage 1** requires one to *identify desired results*, **stage 2**: *determine assessment (acceptable) evidence* and stage 3: *plan learning experiences and instruction*. The design framework can be used at unit or course level.

This course was divided into three units to facilitate its treatment during the learning process. The UbD framework was applied at unit level, namely: The ray model, the Refraction of light, and the Reflection of light. Each of these units had its learning outcomes, assessment evidence, and learning experiences and instruction, all conducted within a given time framework of 15 weeks.

In view of the authors of the UbD framework, the purpose of this design approach is to promote student understanding – meaning the ability to make meaning of "big ideas" and transfer their learning (Mitchell, Keast, Panizzon & Mitchell, 2017). This is revealed through what the authors call six facets of understanding, namely: *the capacity to explain, interpret, apply, shift perspective, empathise, and self-assess*. An overview of the UbD design framework is given in Figure 3.3. In the diagram, an additional element of purpose refers to the purpose of each unit within the entire designed course of study.

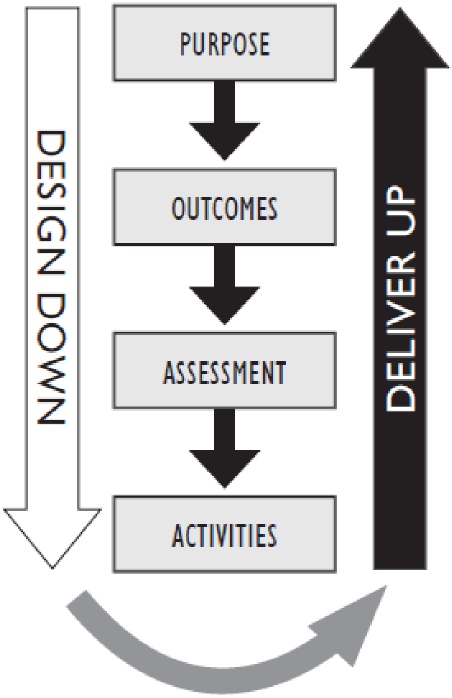


Figure 3. 3 (a)

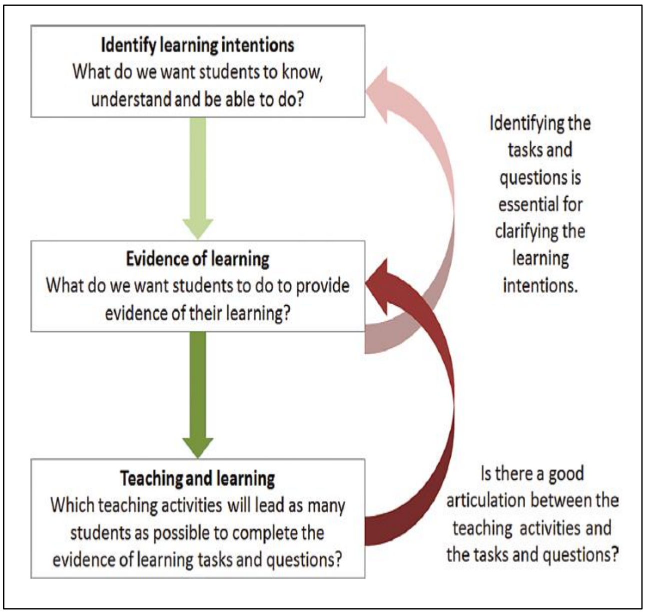


Figure 3.3 (b)

Figure 3. 3: (a) Stages in backward design, (b) Explanation of the stages (Whitehouse, 2014, p. 100)

Figure 3.3 (b) shows that the process from stage 1 to 3 is not linear but iterative, with work on one stage feeding back into revisions and improvements of the others. A favourite teaching activity might be proposed, but there may be difficulty in saying exactly what students are expected to learn from it. If the intended learning outcomes cannot be identified, this suggests that the activity may need amending (Whitehouse, 2014).

3.2.3.3. The first intervention design

Table 3.4 shows the designing stages of the first prototype, which was then used in the first micro study with 2015 student participants. The design had four stages and are explained what each entail.

Table3. 4: Design stages of the initial teaching intervention as informed by theory

UNIT 1 NATURE AND MODELS OF LIGHT
Stage 1.1: Purpose & Content
Purpose: This unit aims to develop in the student a greater understanding of the concept of ray model of light in geometrical optics, by applying it to complex physical situations that combine multiple aspects of physics than presenting concepts in isolation. Due to the complex nature of light, the ray model of light simplifies the subject matter of optics, by describing light in simpler terms. Using the ray model of light enables discussions about the path taken by light, analysis of many devices and other phenomena, without committing to any specific description of what it is that is moving along that path or interacting with the devices. ***Content:*** Discussion of the concept of light in terms of the three models of light: • The ray model & its assumptions • The wave models • The particle model
Stage 2.1: Learning Outcomes
On completion of the course unit students should be able to demonstrate knowledge and understanding of the concept of the ray model of light, so they can: • Define the concept of *ray of light* • State and interpret the assumptions of the ray model of light • Correctly predict the behaviour of light when interacting with a transparent material medium • Explain how observers at different locations may be able to see the same object at the same time • Explain why it is impossible to separate a single ray of light from a beam of rays
Stage 3.1: Evidence of Learning (Assessment)
Students:

- Write an open-ended short quiz about the ray model during class time, first lesson after orientation class. Video lecture content is posted on BB prior to writing the quiz (duration 20 minutes). Quiz meant to motivate students to watch and study content on video lectures.
- Write a one hour open ended test at the end of the study unit.
- Complete lab reports for each lab in the unit

Stage 4.1: Learning Arrangements

(a) Before Class

The following are proposed learning arrangements using video lectures, based on design and implementation principles and overarching design framework for a flipped classroom of Lo & Hew (2017; pp. 224 & 233). Examples (Knight, 2014, pp. 268-290) to show the nature of questions have also been added.

Pre-class video material, each limited to six minutes, is designed and disseminated with the following stages in mind:

Activation – *Revision videos* designed for recall of previous knowledge relevant for learning the new knowledge, especially for underperforming students form this initial stage. This creates the base avoiding students viewing the new knowledge as something disjointed from what students experienced before, thus making it easier for them to assimilate the new content.

Demonstration - Videos disseminating new content at this stage are provided and explain new concepts such as *the concept of a ray and its significance in geometrical optics*, *assumptions of the ray model*, *assumptions of the particle & wave models*, *strengths and limitations of each model*, *the difference among these models*, *the conditions under which each model is applicable*, *the importance of each model in the physics of optics*. Instructor also shows the type of questions designed to promote conceptual understanding, as well as how to solve or answer them. Sample example: *What is meant by the ray approximation in optics? Under what conditions can one use the ray approximation to describe the transmission of light?* The question can only be answered if the student understood the conditions that determine when each model is applicable.

Application – focus at this stage is to provide an extra set of questions and problems that gives the students the opportunity to consolidate their understanding of the content studied at activation stage. The students may work individually or with colleagues. Depending on the preference of the instructor, the exercise may provide the student the opportunity to answer the question and receive immediate feedback (online exercises). The nature of the questions is still at level of recall and comprehension. An example could be as follows: *A person looks at a tree illuminated by the sun during day time, light rays leave the object - A. only from points at the top and base of the tree, but in every direction, B. from every point on the surface of the tree, but only toward your eyes, C. only from points at the top and base of the tree, but only toward your eyes, D. from every point on the surface of the tree and in every direction.* The question seeks to test if the student understood five assumptions of the ray model.

Online interaction – this is a proposal that there be provision for online question-and-answer interaction, where the instructor or teacher is available, for students to ask and receive immediate feedback.

Pre-lesson worksheets – this is a proposal where worksheets with conceptual and quantitative questions on the nature and models of light may accompany the videos material as well, to ensure preparation for the class. This may work well if there are problems with the online space or learning management systems (LMS). Out-of-class activities should help determine how face-to-face lessons are to be designed and implemented.

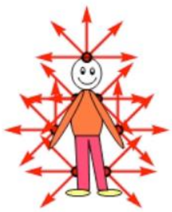
(b) In-Class Learning Arrangements

The in-class design and implementation principles and overarching design framework for a flipped classroom, in accordance to Lo & Hew (2017; pp. 224 & 233), propose the stages described below. Some of these stages have examples (Knight, 2014, pp.268-290) given to show the nature of problems applicable to the stage.

Activation – The lesson is approached focusing on activation, application and integration stages. It may start by a brief review of the content viewed by students through online videos (mini lecture), or may start by making students write a brief quiz about *nature and models of light*, as was the case in this study, to test students' level of preparedness. The quiz is discussed during class time and graded as well, as a mechanism to oblige students to watch the online video material. The discussion of the quiz forms part of the brief review of the key concepts before engaging students in the application of the key ideas presented online.

Application – tasks designed for implementation at this stage may need to take into consideration ability levels of students, such as allocating the more basic exercises to underperforming students, and advanced problems to high ability students. Tasks are provided as a set of questions or problems on a worksheet, ranging from simpler to the much complex ones. Provision is given for students to choose which questions/problems to start with from the worksheet, to accommodate both the underperforming and high ability students. Students are expected to apply concepts and knowledge acquired during the out-of-class preparation phase of FCA to simple problems. Small-group learning environments where students learn from each other by discussing problems, explaining procedures and confirming answers are organised by the instructor to encourage peer-supported learning.

Integration is the stage where the students present their solutions to the class after working in groups, and are expected to fully explain their procedure to their classmates. In cases where students may not be able to complete some of the tasks in class, these are left to be done at personal or group level as homework outside the class. *By analysing what is happening to the figure below,*



--- explain how it is possible that people standing at different locations but near each other, in an open space during day time, are able to see each other at the same time.

The nature of the problems at this stage should be real-world context type advanced problems. The problems should be advanced in the sense that they should force students to think linking their theoretical knowledge to what really transpires in real life. Thus questions are very practical in nature. The questions could be qualitative as the example given above or quantitative where calculations are involved. The discussions also take place in peer-supported learning environments. FCA is a highly interactive instructional approach where one to one and small-group tutoring is encouraged.

UNIT 2
REFRACTION OF LIGHT

Stage 1.2: Purpose & Content

Purpose:
The focus of this unit is to develop student conceptual understanding of the principle of refraction and ability to interpret mathematics physically.

Content:
- Refraction of light at plane surface
- Total internal reflection
- Refraction of light at curved surface

Stage 2.2: Learning Outcomes

On completion of the course unit, students should be able to demonstrate knowledge and understanding of the principle of refraction of light so they can
:
- Explain the concept of refraction and the law of refraction, with respect to behaviour of light and its speed at an interface between two transparent mediums, using appropriate diagrams or relevant mathematical formulas.
- Explain with the support of relevant formulas and diagrams, how the speed and wavelength of light changes, when light travels from one medium to another.
- Explain the phenomenon of total internal reflection and use Snell's law to identify conditions under which total internal reflection (TIR) occurs, showing on a diagram the direction of the incident ray, refracted ray and reflected ray.
- Given the necessary information in a problem involving refraction of light at plane surface, solve to determine the requested physical quantity, using the appropriate mathematical formula.
- Determine by ray tracing the location of the image of a real object located inside or outside the focal point of the lens, and state whether the resulting image is upright or inverted, real or virtual.
- Use the thin lens equation, lens maker formula or magnification formula and the sign convention to determine the position of an image or object from the lens, given the necessary information in a problem involving refraction of light by one or two lenses.
- Use the lens maker's equation to determine whether the focal length of a lens is increased or decreased as a result of a change in in the curvature of its surface, or in the index of refraction of the material of which the lens is made or the medium in which it is immersed.

Stage 3.2: Evidence of Learning (Assessment)

Students:

- Write an open-ended short quiz about refraction during class time based on video lecture content posted on BB, after orientation of the new topic in the previous class. Content is posted on BB prior to writing the quiz, in form of a video lecture (duration of quiz 20 minutes). Quiz meant to motivate students to watch and study video lecture material.
- Write a one- hour open ended formative test immediately after completing course unit.
- Complete lab reports for each lab in the unit

Stage 4.2: Learning Arrangements

(a) Before Class

The proposed learning arrangements for this section are just the same as has been described in stage 4 of unit 1 part (a) (Stage: 4.1(a), and are based on the principle of design and implementation and overarching design framework for a flipped classroom of Lo & Hew (2017; pp. 224 & 233). Thus no repetition of the description of activation, demonstration, and application is given here. Only examples (Knight, 2014, pp. 268-290) are given and their purpose explained.

Activation – the video content of which students are expected to understand before class meeting includes *the concept of refraction defined in terms of change of speed of light in mediums of different optical density, the law of refraction in its mathematical form and its physical implications, conditions leading to total internal reflection and the concept itself, behaviour of light through optical systems such as the lens and the associated mathematical formulas*.

Demonstration – the activity serves to show how students can improve their understanding of what has been taught at the activation stage, by answering questions provided at the next stage of application. Thus an example of questions that students may be shown on how to apply the concepts studied may read as follows: *Using your knowledge about the ray model of light, explain why a ray of light undergoes refraction when it passes from one medium to another*. The question seeks to check if the student realises that the change in direction, in terms of the ray model of light, is caused by a change in the properties of the medium. It also serves to help the student understand that knowledge about ray model serves to explain phenomena studied under refraction, hence the two units are one block of knowledge, and that refraction builds upon the ray model of light.

Application – this stage comprises of a set of questions or problems or a mixture of the two, where mainly the focus is on conceptual understanding. An example of such tasks may be as follows:

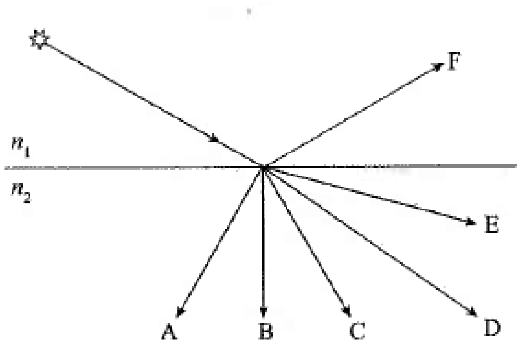
> *The refractive index of a medium ‘x’ with respect to ‘y’ is 2/3 and the refractive index of medium ‘y’ with respect to ‘z’ is 4/3. The refractive index of medium ‘z’ with respect of ‘x’ is: (a) 2/9 (b) 9/8 (c) 1/3 (d) 5/6.*

(b) In-Class Learning Arrangements

According to design and implementation principles and overarching design framework for a flipped classroom of Lo & Hew (2017; pp. 224 & 233) this section should be organised in stages of activation, application and integration. These three stages have already been described what they entail in Stage 4.1 (b). In this section only examples (Knight, 2014, pp268-290) are provided to show the nature of questions that can be discussed in class.

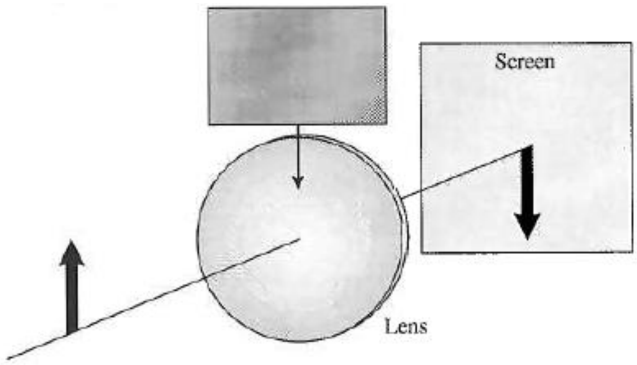
Activation – this stage is about reviewing the content's key ideas studied by students through video lectures. Students also write a quiz whose marks become part of the course grade [see Stage 4u1 (b)]. A sample question for the quiz is shown below:

The diagram shows six possible trajectories of light rays leaving an object. Which, if any, of these trajectories are possible? For each that is possible, what are the requirements for the index of refraction η_2?



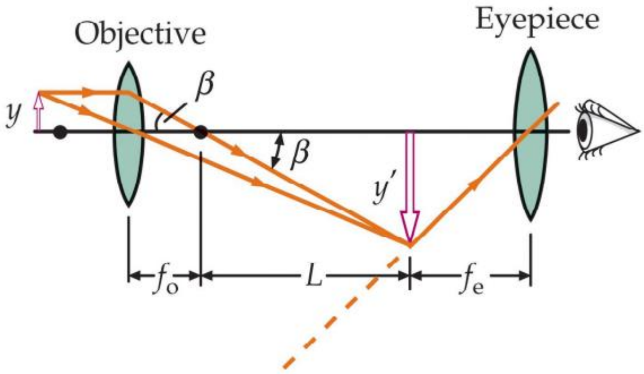
Application – this stage involves designing and implementing a set of discussion problems on a worksheet [see Stage: 4.1 (b)]. A sample of the discussion type questions is given below:

An object and lens are positioned to form a well-focused inverted image on a viewing screen. Then a piece of cardboard is lowered just in front of the lens to cover the top-half of the lens. Describe what happens to the image on the screen. What will you see when the cardboard is in place?



The worksheet, in addition to this type of questions, should also have quantitative type of questions involving calculations. The nature of the questions should be such that it forces students to think in order to develop their critical thinking skills. The instructor constantly checks on how groups are discussing these questions as he/she moves around the tables, at times probing the groups with his/her own questions especially where difficulties are encountered.

Integration – the results of the discussions from the groups are presented before the entire class and discussed. Resolutions are then taken with the guidance of the instructor by summarising key findings. The worksheet must be designed with problems that are more than what can be discussed in class, such that some problems are discussed in class, and some are left for individual work after the class. The nature of the tasks on the worksheet should be real-world context type advanced problems where questions are very practical. Example:

A microscope is an example of a two lens ray tracing problem, but the distance between the lens and where the object is placed are specific to the microscope. The focal points cannot overlap and the object is placed very close to, but outside the objective lens focal point.  	*You have two lenses for making a compound microscope: f_o = 0.800 cm and f_e = 1.20 cm. How far apart should you set the lenses to get a magnification of –300? (Assume the normal near point of 25.0 cm.)*

UNIT 3
REFLECTION OF LIGHT

Stage 1.3: Purpose & Content

This unit is aimed at developing in students, knowledge and understanding of the theoretical underpinnings of the phenomenon of reflection, and the formation of images in mirrors through ray-tracing techniques.

Content
- The concept of reflection of light
- Laws of reflection of light
- Reflection in plane and curved mirrors

Stage 2.3: Learning Outcomes

On completion of the course unit, students should be able to demonstrate knowledge and understanding of the principle of reflection of light so they can:

- Use the definition of reflection of light, to qualitatively or quantitatively, locate the position of an image, or determine its size, in a problem involving a plane mirror.
- Given a diagram of any polished surface or non-polished surface, define the type of reflection involved, and explain the circumstances under which it occurs, using your knowledge about the nature of the surface at microscopic level.
- Given a diagram of a mirror with focal point shown, locate by ray tracing the position of the image of a real object, and determine whether the image is real or virtual, upright or inverted, enlarged or reduced in size
- Given the necessary information to determine an unknown quantity in a problem involving mirrors, be able to represent the information in a diagram, and use the correct lens or magnification formula, to correctly determine the unknown quantity.
- Effectively use the sign convention, in a problem involving one or two mirrors, given all other necessary information, to predict qualitatively or quantitatively the solution to the problem.

Stage 3.3: Evidence of Learning (Assessment)
Students: • Write an open-ended short quiz about reflection of light during class time, based on the video content they watched, first lesson after their orientation on the new topic in the previous class. Content is posted on BB prior to writing the quiz, in form of a video lecture (duration of quiz 20 minutes). Quiz meant to motivate students to watch and study video lecture material. • Write a one- hour open ended formative test immediately after completing the course unit. • Complete lab reports for each lab in the unit

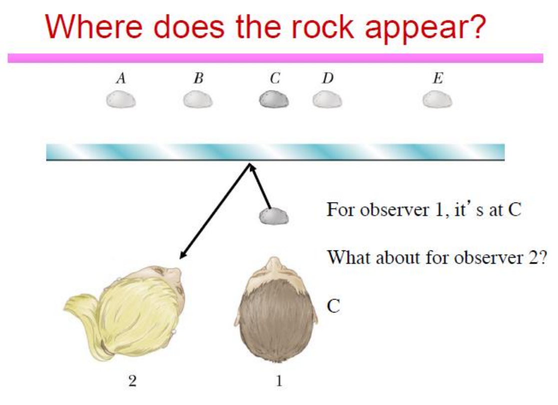
Stage 4.3 Learning Arrangements

(a) Before Class

The approach to how video lectures should be prepared has already been described in Stage: 4.1 (a), which divided into *Activation*, *Demonstration*, and *Application*, in accordance to design and implementation principles of Lo & Hew (2017; p. 233) for out-of-class learning. In this section, only examples (Knight, 2014, pp. 768-790) of the nature of the tasks are be provided.

Activation – video lectures will be expected to discuss the phenomenon of reflection in terms of definition of reflection, the law of reflection, image formation in plane and curved mirrors, ray-tracing techniques (and sign convention), and total internal reflection.

Demonstration – An instructor demonstrative question, that can show the type of questions needed to consolidate conceptual understanding in students, may read as follows:

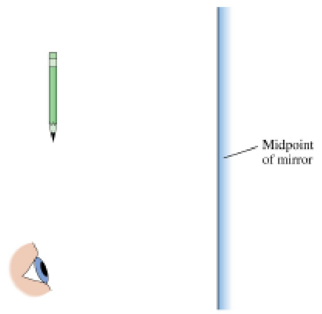


The question is meant to show how students may have to use ray tracing techniques in mirrors and the law of reflection to identify the position of the image.

Application – at this stage, a set of other questions the students can practice on his/her own are provided. The questions still serve the same purpose of developing conceptual understanding in the student. The questions may be on a worksheet, or be part of a video presentation, or may be given through a computer programme that asks the questions and the student answers them, receiving feedback immediately. A sample type of such questions is given below:

You are looking at the image of a pencil in a mirror. What do you see in the mirror if the top half of the mirror is covered with a piece of dark paper?

A. The full image of the pencil
B. The top half only of the pencil
C. The bottom half only of the pencil
D. No pencil, only the paper



It should be noted that the questions are not restricted to multiple choice type, but can also be short answer questions, both qualitative and quantitative, provided they are designed to fulfil the purpose of the pre-class online individual session.

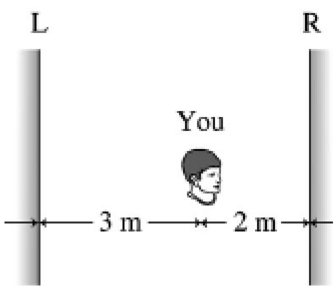
(b) In-Class Learning Arrangements

As in Stage: 4.1(b), stages for conducting in-class activities are to start with *activation*, *application* and *integration*, in accordance with design and implementation principles and overarching design framework for a flipped classroom of Lo & Hew (2017; pp. 224 & 233). Details of how this is to be done have already been given and are not repeated in this section. Only examples (Knight, 2014, pp. 268-290) of the nature of tasks are given.

Activation – This entails students writing a quiz, its revision, giving a mini-lecture with demonstrations where clarification is needed and addressing students' questions [see details Stage 4u1(b)].

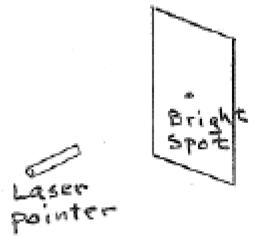
Application – students attend to worksheet problems of various levels of difficult in groups. An example of the nature of the questions is given below:

The place you get your hair cut has two nearly parallel mirrors 5.0 m apart. As you sit in the chair, your head is 2.0 m from the nearer mirror. Looking toward this mirror, you first see your face and then, farther away, the back of your head. How far away does the back of your head appear to be? Neglect the thickness of your head.

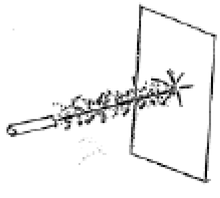


Integration – A sample of real-world application problem that could be discussed in a small-group learning environment, with its findings presented before class for further examination by the whole class may read as follows:

In a dark room, a student shines a laser pointer so he could see a spot of light on the wall but could not see light going from the laser pointer to the wall. He tried to place his hand (like a screen) along the straight line connecting the laser to the bright spot on the wall – he noticed that the bright spot disappears from the wall. He also noticed that if he placed his hand along a straight line connecting the spot on the wall and his eye, he could not see the spot.



The student then repeated the experiment, but this time sprinkled chalk dust along a line from the laser pointer to the wall. He now could see the path of the light from the laser to the wall that it is a straight line. How can the student explain his findings?



The question is intended to make students think and come to realise that we can only see surfaces of objects illuminated by light but not light itself. The path of light is a straight line – from the source of light to the object and from the object to our eyes. In the experiment, the path could only be seen because light reflects off the surfaces of the tiny pieces of chalk dust into the student's eyes.

3.2.3.4 Implementation of the first intervention design

Once the first theoretical intervention or prototype was designed and developed, the content had now to be taught and learned by the instructor and learners respectively. UbD helped to structure the content for each unit as guided by the learning outcomes and objectives, and by specifying what exactly needed to be assessed from these learning outcomes, the corresponding learning activities were able to be designed.

Now the teaching process had to follow being guided by what had to be assessed, or the evidence that learning had taken place. Thus, designing was downward, and implementation was upward. UbD informed how to design the intervention following a downward process indicated in figure 3.3, while the teaching-learning process was conducted as a reverse process. The assessment activities are at the heart of the design for their role is to bring alignment between learning activities and the learning outcomes.

However, the overall process, from principles guiding the design of activities included in the intervention, through the designing and development processes, until evaluation of the intervention, was done following the FUNKEN-model of topic-specific didactical design research (Prediger & Zwetzschler, 2013) shown in figure 3.4.

The FUNKEN model (Figure 3.5) shows four working areas which are: S*pecifying and structuring learning goals and contents* which entails identifying key scientific concepts, principles, laws, and theories students have to acquire from the formal content. The procedures and how to justify their use must be identified as part of specifying goals or content. Furthermore, structuring the goals or content implies considering how the concepts can be sequenced, how concepts are connected, and how to elaborate the connections and sequences (Gravemeijer & Prediger, 2019). *Developing the design* is about identifying design principles and planning of the teaching-learning arrangements taking into consideration suitable contexts and appropriate instructional activities. *Conducting and analysing design experiments* refers to the implementation of the designed teaching-learning arrangements, and analysis of the processes involved is done. *Developing local theories on teaching and learning processes* refers to retrospective analysis of observations made related to the learning experiences students went through in order to come up with teaching ideas, specific to that particular context, after considering typical conditions and their effects. This didactical design tells us what was happening at each micro-study level in the topic of geometrical optics before the next iteration.

According to UbD, once the activities were designed, the intervention had then to be tested in real classroom setting. Thus, the next sections describe the 3rd stage (conducting & analysing design experiment) of the FUNKEN model, which in this case is about the context, data gathering, and data analysis methods employed in the collection of evidence for proving the effectiveness of the intervention. Already the first and second stages of FUNKEN model have been addressed by the UbD model. The implementation of the intervention at this stage was considered a pilot study, of which the evidence collected was meant to identify defects in the theoretical design. Thus, the first

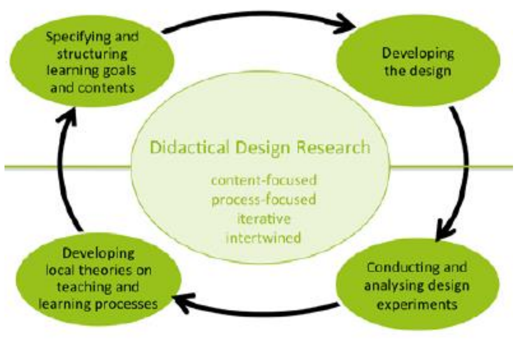


Figure 3. 3: The FUNKEN model for didactical design research (Prediger & Zwetzschler, 2013)

participants were used as a pilot group to help with the adjustments needed to come up with a more realistic intervention for the real study.

3.2.4 Phase 2: Prototyping phase

A sequence of prototype interventions was tried out and revised on the basis of analysis of data collected using the instruments, namely: Light and Optics Conceptual Evaluation (LOCE) pre and post-test instrument (see section 3.4.2.4 Ia & Ib), SALG questionnaire (see section 3.4.2.4 IIa & IIb) and an interview protocol (see section 3.4.2.4. IIIa & IIIb). There were four iterative cycles from 2016 to 2019 after the first theoretically designed intervention in 2015, with changes being made to each preceding intervention, based on the analysis of the collected data, to improve the ability of each innovation. These cycles were considered as a stand-alone micro-study meant to fine-tune particular aspects of the previous intervention. Each study was considered a flipped learning activity as well as the unity of analysis from which data was collected to address the research questions. Both quantitative and qualitative data were immediately collected for analysis after implementation of each of the interventions. All studies were conducted in the same physical settings: an open-spaced hall with several working stations from which students conducted their discussions as they worked on specified assigned tasks. Each station had 4 desks grouped together so that students could sit on chairs in a round table format.

3.2.4.1 Context of data collection

This study was conducted from 2015 to 2019 during the first semester of each year as part of a 3rd year physical science course, focussing on the physics component. This component was a geometrical optics course, which for purposes of studying it, was divided into three sub-units namely *ray model of light, refraction of light, and reflection of light*. The course was entirely algebra-based without any calculus sections at all. The instructional period for the entire content was divided into two main parts within the semester. The first part of this period was used purely for academic work at the campus, for a period of 11 weeks, while the second part was reserved for their teaching practice for a period of 4 weeks. On their return from teaching practice students had one week window period for revision in preparation for the end of semester exams. On the university timetable, the course was allocated 2 periods per week as a physical science module made up of two components - chemistry and physics. Each component had therefore one period per week with a duration of $1\frac{1}{2}$ hours. Taking into consideration the background of the students, the time allocation was considered inadequate for building a meaningful conceptual foundation in geometrical optics. So, the students and lecturer sought an extra time allocation also of $1\frac{1}{2}$ hours outside their normal timetable allocation. This was also done to factor in other challenges such as the reduced time for study that was available to students due to their wider curriculum involving other educational courses. Though the course was done in the Department of mathematics, science, and technology education, it was still housed under the School of education.

3.4.2.2 Participants of the study

All participant involved in this study were pre-service teachers in their 3rd year of study. The total number of participants, considering the entire duration of the data collection process was 589. The first micro phase study of 2015 had 95 students, the second of 2016 had 113, the third of 2017 had 130, the fourth of 2018 had 146, and the fifth of 2019 had 125. All participants were students majoring in physical science and mathematics and were being professionally trained to become teachers. Their physics background in geometrical optics was not that strong as it was based in what they last studied in grade 11 at high school, which was not much within the context of South African educational system CAPS curriculum document (DBE, 2011). Thus, only at third year level of their study, the students engaged with the content at greater depth and breadth for the first time.

3.4.2.3 Testing and refining the intervention in real-life contexts

According to Kennedy-Clark (2013, p. 26):

> *"As design-based research aims to ascertain if and why a particular intervention works in a certain context, micro research phases provide researchers with an opportunity to refine the design and to gain a more informed understanding of why an intervention may (or may not) work in that context".*

Taking into consideration the aim of DBR described by Kennedy-Clark above, this section describes how each of the four interventions were implemented and refined during the course of the study. The iterative cycles helped the researcher to gain understanding of how the final design product would work in similar contexts. Each intervention was treated as a micro case study of its own but contributing to the outcome of the entire study. Since the implementation process was similar in all four cases, the description provided in this section is generic, focusing on the general procedure followed and common to all micro cases.

To facilitate the implementation of the intervention, the course content was divided into three smaller units, as has been indicated in the context section, namely the *ray model of light, refraction of light, and reflection of light*. On completion of each of these units, an end of unit test was given to students after six lessons, conducted at the rate of two per week. Eventually students would write the final semester examination. These tests and the semester examination played a formative function helping to identify areas of weaknesses where assistance was needed.

Since the instructional model used in this study was the FCA, direct instruction of the course content was delivered to the students prior to the class meetings using video lectures. This was a common strategy employed to all four micro case studies. The purpose was for students to prepare before class meetings, where concept application was the main activity within the face-to-face classroom session. The sequence of activities (Figure 3.5) during the out of class preparation phase was conducted according to Merrill's first principles (see section 3.4.1.1)

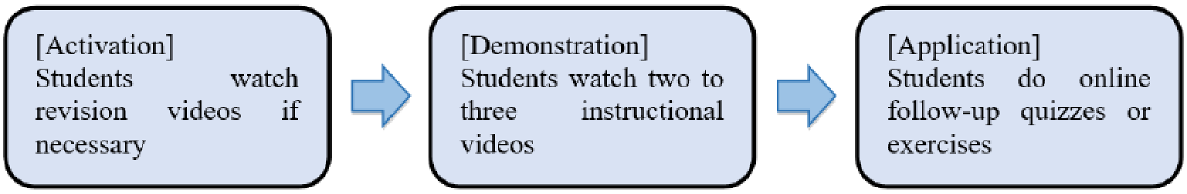


Figure 3. 4: Out of class video lecture sequence of activities (Lo & Hew, 2017)

In this study, most of the video lectures used were searched, selected, and downloaded from the internet on you tube. Some of the videos at the time the study commenced did not meet the guide given in figure 3.6, but mainly concentrated on activation, where lecturing of basic facts without demonstration or application of how to use these concepts was done. There were no recall questions accompanying the video lecture.

Students were exposed to recall questions during the face-to-face class session in form of a quiz that was answered first thing before the commencement of the class. This was done to ensure all students would attend the in-class session, as well as prepare for it, since the quiz was made to contribute to their final semester mark. Another reason for not including the quiz as part of the video lectures was to check if students were watching the video lectures rather than merely reading the textbook alone and using it to answer the quiz. The quiz questions were framed to match what the presenter had discussed during the video lecture. However, the face-to-face contact sessions for discussions in class were reasonably adjusted to accommodate Merrill's propositions (Figure 3.7), as well as the constructivist learning principles described and summarised in table 3.2.

Thus, as part of activation during the class session, the quiz answers were discussed immediately after students finished writing it. The content presented during the video lectures was reviewed, student questions related to the video lectures were also addressed. Thereafter a demonstration on how to apply concepts presented in video lectures using simple problems was done by the instructor, followed by simple tasks given to students to work on, at times individually, and at times in pairs. Student-instructor interaction came into play when students had to present their responses to the questions given to them, and they had to defend their reasoning before the entire class, with instructor probing whenever necessary to seek clarification from the presenter. The more difficult questions were done in groups consisting of five members. These groups were formed by students themselves according to whom they preferred to work with. Usually, the more difficult questions could not be completed in class, and therefore became part of the homework to be presented in the next class. Students had therefore to meet in their groups after class to complete the homework.

As reference material for homework after the class session, students used Knight's textbook (2008), because this was the textbook easily available to students where geometrical optics was discussed after introducing the concept of ray model of light. Most of the physics textbooks do not explicitly talk about the ray model of light and its assumptions. The book treats the ray model separately and explicitly from the wave model of light, giving two distinct descriptions of models of light that have different validity ranges. The video lectures on ray model of light (InvariantSpace, 2011) showed students how the ray model of light differed from the wave model of light by analysing the diffraction equation. The textbook provided further clarification in

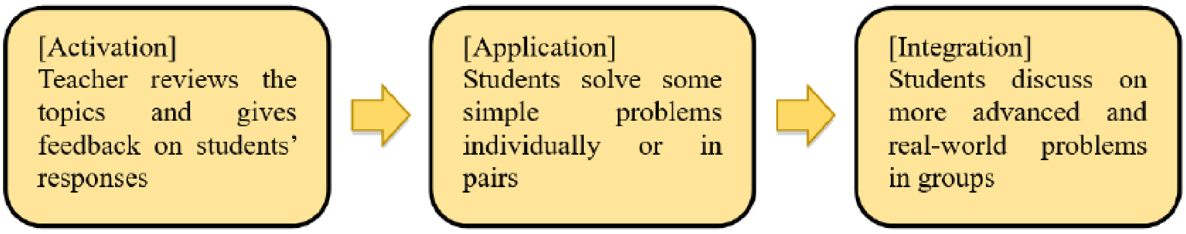


Figure 3. 5: In-class sequence of learning activities (Lo & Hew, 2017)

support to the video lectures especially to students who were struggling with this concept.

The effectiveness of the interventions was assessed and evaluated by collecting and analysing quantitative and qualitative data. Three instruments were used to collect the data: the Light and

Optics Conceptual Evaluation (LOCE) which was used during pre and post-tests, the Student Assessment of Learning Gains (SALG), and an interview protocol, which are described in the following section.

3.2.5. Phase 3: Assessment Phase

The assessment phase was the last stage of the investigation where the final practical product and design principles were formulated, and recommendations for future work generated (Kennedy-Clark, 2013). At each micro-cycle, principles were identified from data collected in terms of what students could identify as elements (content, structure, instructional strategies, etc.) of the designed intervention which were notably important in improving their understanding of the content to a greater level. In addition, principles were also refined in terms of elements identified as being unimportant or misleading or non-effective in improving their level of understanding of the subject matter content. Because each intervention and its related design principles was subjected to an evaluation process, involving data being re-examined and reflected upon, production of subsequent re-designs and their refinements was considered to produce better versions of interventions than their predecessors. Thus, key elements identified from students' data analysis from the implementation of all the interventions were used to formulate the design principles of the final design product. These were key ideas drawn from outstanding aspects identified from the data analysis linked to each prototype intervention, mostly selected based on themes that featured most in data analysis of the interviews and open-ended questions from the SALG data, as well as those components from the closed-ended questions of the SALG instrument that featured most during the data analysis.

In order to understand how the assessment phase was carried out, an example of how the process unfolded is given in this paragraph using the pilot grou<of 2015. The SALG survey instrument at the piloting phase had ten major questions, but each with its own subitems. The survey data for the closed-ended section were analysed using Factor Analysis statistics method. The statistical method grouped together items that make up the same construct or factor (See section 4.2.1.6). There were thirteen factors identified by the analysis (see Table 4.4). The factors were named by proposing constructs that best represented each of the items making up the factor. Thus, the findings of the pilot study for the survey closed ended section were thirteen constructs as listed in section 4.2.1.6. Each of these was further examined to identify where it suitably fits within the framework of FCA.

The open-ended section of the survey was also analysed using content analysis (see Appendix E and Appendix F). Participants’ views were examined in terms of positive sentiments, which were taken to be the strengths of the intervention, and negative sentiments, which were taken as areas of difficulty and needing improvement in designing the intervention (see section 4.2.2). The views were grouped to form constructs which became major findings for that particular micro-study.

The same procedure was followed with the interview instrument as described in section. Findings were also grouped as strengths and weakness according to what participants pointed out as positive sentiments and negative sentiments.

3.3. INSTRUMENTATION

There were three instruments used to collect data in all four micro phase studies, namely: Light and Optics Conceptual Evaluation (LOCE) test instrument for quantitative data, the Student Assessment of Learning Gains (SALG) instrument for quantitative and qualitative data, and the interview protocol instrument for qualitative data.

3.3.1 The LOCE instrument

The LOCE is an instrument that was developed in 2003 by Sokoloff (2006) with the aim of examining conceptual understanding of basic geometric and physical optics for the Active Learning in Optics and Photonics (ALOP) program administered by United Nations Educational and Scientific Organization (UNESCO) (Thapa & Lakshminarayanan, 2013, July). It is a test of 51 items covering a variety of areas in introductory optics. The question distribution was four (4) on reflection and mirrors, five (5) on Snell’s law, seven (7) on lenses, fifteen (15) on imaging, two (2) on visual optics, eight (8) on polarisation and scattering, eight (8) on wave optics, interference and diffraction, and a ray tracing exercise. Among the multiple-choice questions, four of the questions required students to provide brief written explanations on spaces provided on the question paper, justifying the choices they made. Care was taken to ensure the instrument used in this study only included questions having direct relationship to geometrical optics. Thus, questions on polarisation and scattering, wave optics, interference and diffraction were excluded. Most questions were concept-based with minimal calculations needed.

3.3.1.1 Validity and reliability of the LOCE instrument

The validity and reliability of the instrument lies in that it is a research-based assessment instrument that was developed over time by physics specialists and has been applied in other studies measuring conceptual understanding of students (Sokoloff, 2006; 2012; 2017). According to the authors of the instrument (Sokoloff, 2006), the answers to the multiple-choice questions (both correct and incorrect) are based on common models students have on physical systems, which have been identified through extensive research conducted through student interviews and students answers to open ended questions. Because of the research-based nature of the answers, student models before and after instruction can be evaluated, leading to the design of new instructional materials (Alarcon et al., 2010, August).

3.3.1.2 Procedure for data collection with LOCE instrument

The LOCE instrument was used to assess students' knowledge status before instruction began, and after completion of instruction, without changing its form. The pre-test was administered to assess the students' level of conceptual understanding of the content that was being taught. The assessment post instruction was meant to determine how much of the same content students were taught had been retained.

Manual, D. S. A. T. (2006), argues that research acknowledges the use of identical test in pre-post-tests designs, and that gains attributed to students taking the same test a second time are insignificant, provided no revision is done before the post-test. Sanders (2019) on the other hand, recommends that different versions of the instrument be used for pre- and post-tests. The assumption was that students will be familiar with the test questions when they write the post-test. However, Sanders also went to caution that the use of an alternative form of a post-test may result in alteration of the level of difficulty of the instrument. Thus, the change in scores noticed after administration of the pre- and post-tests may not reflect students' abilities but the difference in the difficulty of the two different forms of the instruments. It was on the understanding of this second point that the instrument was implemented without altering its form. The idea was to ensure the quality and level of difficulty remained the same, prior and post instruction. The instrument was used as it was before instruction and, for after instruction. For the same reason, it was used across all three groups after the pilot study.

Furthermore, students wrote the pre-test without prior notice, and all question papers were collected by the researcher. There was no revision done to the test as suggested by Manual, D. S. A. T. (2006). Students were informed the test was for diagnostic purposes and that the instructor would use the information for planning lessons. They were not informed about writing a post-test at the end of the semester. The instructor also did not think students would easily remember the questions exactly as they were, after a fifteen-week semester in which they were also subjected to other tests.

In 2015, the number of students enrolled in the course was 95. No LOCE pre-post-test was conducted because the instructor was still working on the theoretical model of the intervention. As such the effectiveness of the theoretical model of the intervention could not be tested through quantitative data means of student academic performance.

The 2016 group of students enrolled in this course were 113. The LOCE pre-test was administered to measure the level of understanding of students in geometrical optics concepts before instruction began. The number of students who wrote the pre-test were 95. Those who did not write the pre-test for various reasons were 18. However, students did not write a post-test in this cycle due to students' unrests at the campus.

In the 2017 cohort there were 130 student participants enrolled in the course. All students wrote the LOCE pre-test at the beginning of the semester. The number of students who wrote the LOCE post-test were 129. The LOCE instrument was the same copy used in 2016 during the pre-test.

The 2018 student cohort had 146 student participants. The number of students who wrote the LOCE pre-test were 133 at the beginning of the semester. There were 13 students who did not write the LOCE pre-test due to varied reasons. At the end of the semester, all students (N = 146) wrote the LOCE post-test. The LOCE instrument was the same copy used in 2016 and 2017 during the pre-post-tests.

In 2019, the total number of student participants in this cohort was 125. The study had 102 student participants who wrote the LOCE pre-test at the beginning of the semester, and all 125 students wrote the LOCE post-test at the end of the semester. The LOCE pre and post-tests were no different to the ones given in the previous year (2018).

3.3.1.3 Analysis of the quantitative data from the LOCE instrument

The quantitative data analysis for the LOCE instrument mainly focused on the 2017, 2018, and 2019 groups of student participants since these were the groups that wrote both pre and post-tests in this study. The analysis was done using one way analysis of covariance (One Way ANCOVA), with SPSS version 26. ANCOVA is a statistical method used to compare the means of two or more groups, on whether the means are equal or not after controlling the effects of one or more confounding variables (termed covariate). If the effect of the covariate is not controlled in the analysis, this may lead to incorrect conclusions about the effect of the independent variable on the dependent variable. In this study, the pre-test was used to measure the level of conceptual understanding of geometric optics of the student participants. This prior knowledge was considered as a variable that could possibly influence the score of the post-test after instruction. In the analysis that followed, the means of pre-test-scores was taken to be the covariate, while the post-test measured the outcome of the effect of the intervention. The outcome was the means of the post-test scores and was the dependent variable in the context of ANCOVA. Thus, the comparison between the means of the post-test scores, for the three groups of 2017, 2018 and 2019, was of adjusted means that factored in the effect of the prior conceptual knowledge of the participants.

Further analysis was also carried out to ascertain the effectiveness of the intervention by determining the normalised gain (G) (Hake, 1998) for each of the microstudies using SPSS version 26, thus enabling making conclusions on the extent of the effectiveness of the intervention on each group.

3.3.2 The SALG instrument

The SALG instrument was designed with the intention of facilitating formative evaluations. It was designed to flash out course elements "that best support student learning and those that need improvement" (Seymour, Wiese, Hunter & Daffinrud, 1997; p. 1). The design nature of this study was grounded on the use of various formative assessments, culminating in a designed product of an intervention, with components that best support student learning in a geometrical optics course. Thus, because of the nature of the design intentions of the SALG instrument, which were largely formative, it was considered the appropriate instrument to use year after year with each student cohort. Elements that supported student learning, and those that needed improvement, were revealed on analysis of the instrument. The instrument consisted of statements on how students perceived their gain in certain aspects of the class, such as in-class activities, assessment activities, learning resources, among others. This therefore allowed the instructor to discover how the course contributed to student learning, and appropriate adjustment to the instruction to be taken.

3.3.2.1 Description of the SALG instrument

The Student Assessment of Learning Gains (SALG) questionnaire (see appendix D) was an adaptation of Seymour, Wiese, Hunter & Daffinrud, (1997)'s survey instrument. This is a web-based instrument "*that provides information about specific gains that students perceive they have made in any aspects of a course that instructors have identified as important to their learning*" (Seymour, et al., 1997; p. 3). The instrument was a closed questionnaire that sought students' opinion about the effectiveness of the intervention in various aspects. There were 6 response categories provided from which students were expected to choose only one under the closed items. The questionnaire comprised of 10 major questions falling under specific constructs with each construct clustered by 3 or more sub-items describing that specific construct. The instrument had also open-ended questions at the end of each of these sections, where students had to write their opinions in the open spaces provided. The sections were named A, B, up to J for easy identification.

The SALG instrument is designed in such a way that it allows instructors the latitude to add, subtract, delete, or edit questions online or in the written format of paper and pencil version. In this study the paper and pencil version were used. In its web-based format, the instrument can be quickly used to analyse data in formative assessments carried out by instructors (Scholl & Olsen, 2014). The instrument is used to identify elements that can support learning, as well as those that need improvement in a course, as students indicate what they had gained from each of these elements.

3.3.2.2 Validity and reliability of the SALG instrument

According to Caroll (2015), the validity and reliability of the instrument lies in the fact that the stem questions and scales used are fixed to preserve the validity and identity of the instrument, as well as to make it useful as a research instrument. The fact that it has been in use, and subjected to ongoing development since 1997, has been used by over 12 000 college and university instructors, and is accepted as evidence of student learning by many accrediting bodies shows how reliable the instrument is (Caroll, 2015). In this study, only part of the entire instrument was used on the microstudies of 2017, 2018 and 2019, after the instrument was piloted. To improve the validity of this short version of the SALG instrument, other physics lecturers in the department who have had experience in teaching the course as well as those involved in teaching science methods were consulted for their input.

3.3.2.3 Procedure for data collection with SALG instrument

In 2015 the design process of the intervention was not yet finalised. The intervention was tested on students as a pilot study in which the SALG questionnaire was used as the instrument of data collection. The instrument was very long with all of its sections as adopted from the source. Students' opinion about the instrument was that it took more time to fill it in. They needed more than an hour to complete it and were not so keen to dedicate such a time. The instructor had to adjust the questionnaire, and decide what sections to leave out, but leave those he felt most relevant to the study. Consultations were made also to senior staff within the physics discipline on what to include on the amended questionnaire without altering the essence of the instrument.

In 2016, the SALG survey questionnaire was given to all 113 students at the end of the semester, but only 75 of them returned their filled-up responses. The survey instrument for this group was no longer the same as the one used in 2015. This time, instead of having sections running from A to J, the sections were contracted to three major sections, A, B and C only. There were also some changes to the sub-items. Section A had 13 closed ended sub-items in total, focusing on the content studied, and one single open-ended question at the end of that section. Section B focused on the instructional approach used to deliver the content and had 14 closed ended sub-items and one single open-ended sub-question. The last section C sought to find out students' attitude towards the module. There were 7 closed ended sub-items in this section and one single open-ended question. The instrument had therefore a total of 34 closed ended sub-questions and 3 open-ended sub-questions. There was no interview conducted with this group due to students' unrests.

The same SALG questionnaire of 2016 was given to all students in 2017 on completion of the module at the end of the semester, and 127 students returned the questionnaire. In 2018, all students answered the SALG questionnaire and returned their responses as well. The SALG survey instrument was the same as the one used in 2016 and 2017. In 2019, the questionnaire was distributed to all 125 students but only 110 students managed to return the questionnaire after completing it.

3.3.2.4 Analysis of data from the SALG instrument

Data collected from this instrument was part quantitative and part qualitative. The method used to analyse each type of data was the same for all student cohorts. Data analysis for the quantitative part of the questionnaire was carried out using Factor Analysis (FA) statistics, with SPSS version 26, while the qualitative part of the questionnaire used a deductive- quantitative approach (Burnard et al, 2008).

3.3.2.5 Analysis of quantitative data from the SALG instrument

This study was undertaken with the sole purpose of developing principles that could possibly guide instruction when teaching the physics topic of geometrical optics but using the flipped classroom approach. It was therefore necessary to analyse the data collected in this study using methods that could lead to the discovery of such principles as defined by the purpose of the study.

FA is a technique for analysing data sets involving multiple dependent variables (Wlliams, Osman & Brown, 2010). The technique helps to reduce a large number of variables to a smaller set of variables, normally referred to as factors or principal components (Sahin, 2010; Penny, 2011; Vakili, 2018). It also allows the underlying constructs and dimensions of these factors to be established, thus leading to formulation and refinement of theory. Lastly FA provides evidence of construct validity for self-reporting scales. These advantages are some of the reasons why FA was employed in this study.

FA comes in two forms: Exploratory Factor Analysis (EFA), and Confirmatory Factor Analysis (CFA). EFA is used when a researcher's intent is to explore dimensions of constructs to generate theory (or model) in relation to items on a questionnaire (Penny, 2011), while CFA, on the other hand is meant to test a proposed theory (or model) that has assumptions and expectations in relation to the number of factors that can be generated from a data set (Vakili, 2018). This study was not testing any theory but to generate one, hence EFA was used. A five-step approach as defined by Williams et al, (2010) was followed during the data analysis process. These steps involved:

1. determining whether the data was suitable for analysis by FA
2. deciding on how the factors would be extracted
3. deciding on the criteria that will be used to extract the factors
4. deciding on what rotational method would be used

5. interpretation and labelling of factors

Step 1 - testing the quantitative data set obtained for its suitability for analysis by the FA method.

This was done to all data collected at each micro study. There were four aspects that were looked at under this first step:

a. Sample size
b. Sample to Variable Ratio (N : p)
c. Factorability of the correlation matrix
d. Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy/ Bartlett's Test of Sphericity

According to Williams (2010), there is no suitable sample size for employing FA because there is no consensus from literature on what the right sample size should be. The study had five student cohorts, ranging from 60 participants (as minimum) to 130 (as maximum).Taking into consideration the lack of agreement in literature on sample size (McNeish, 2017), this study did not consider sample size as a deterrent factor.

The second aspect that was considered was the sample (N) to variable (p) ratio (N: p), which refers to how the number of participants distributes if they were to be shared among the variables in question. However, as in the case of sample size, there is no agreement in literature on what ratio is suitable (Wlliam et al., 2010; Jung & Lee, 2011; Kyriazos, 2018). Thus, the sample to variable ratio was disregarded as a determinant in this study.

The third aspect considered was factorability of the correlation matrix. This entailed examining the correlation matrix by inspecting it for correlation coefficients over 0.30 (Tabachnick & Fidell, 2013), or $\pm$ 0.30 (minimum), $\pm$ 0.40 (important) and $\pm$ 0.50 (practically significant) according to Hair et al., (2010). A factorability of 0.30 implies the extracted factors would account for approximately 30% of the relationship within the data, meaning a third of the variables share too much variance. The study was conducted with correlation coefficients of 0.40 and above.
The fourth aspect involved determining the KMO Measure of Sampling Adequacy and Bartlett's Test of Sphericity. The KMO is an index that ranges from 0 to 1, with 0.50 considered as minimum value suitable for FA (Hair et al., 2010; Tabachnick & Fidell, 2013). The Bartlett's Test of Sphericity, to be suitable for FA, had to be significant at $p < 0.05$.

Step 2 - deciding on how the factors were to be extracted.

There are several methods that are commonly used to extract factors (Williams et al., 2010) such as principal components analysis (PCA), principal axis factoring (PAF), maximum likelihood, unweighted least squares, generalised least squares, alpha factoring, and image factoring. Principal components analysis (PCA) was employed in this study as it is one of the most commonly used in published literature (Henson & Roberts, 2006; Tabachnick & Fidell, 2013; Thompson, 2004). In addition to this, Thompson (2004) also argues that PCA is used in many statistical programs including SPSS, such as version 26 used in this study. The third reason is that PCA is recommended for use when no priori theory (or model) exists and for preliminary solutions in EFA (Pett et al., 2003).

Step 3 – determining the criteria that was to be used to extract the factors

In the determination of how to extract factors, the use of multiple rules is often recommended as appropriate and desirable (Williams et al., 2010; Thompson & Daniel, 1996; Hair et al., 2010). These include Kaiser's criteria for eigenvalue > 1 rule (Hoyle & Duvall, 2004; Braeken & Van Assen, 2017), the Scree test (Hoyle & Duvall, 2004), the cumulative of variance extracted and parallel analysis (Çokluk & Koçak, 2016; Taherdoost, Sahibuddin, & Jalaliyoon, 2014). Of these four examples, the first three were employed in this study in attempt to reduce the more than 30 items or variables on the questionnaire instrument to fewer factors. All factors extracted had eigenvalues greater than one, and a cumulative variance of 95% (Hair et al., 2010) and the Scree test - a visual and graphical representation technique, were used. Thus, a multiple criteria approach was used.

Step 4 – selecting the rotational method

Rotational method in FA is used when the researcher intends to provide easier interpretation of the extracted factors. The process entails examining a variable on whether it relates to more than one factor, or whether it does not load on any factor, or conceptually does not fit for any logical factor structure. The researcher can then decide to discard or keep the variable. There are two common rotational techniques: orthogonal and oblique rotation. In orthogonal rotation, factors are uncorrelated to one another in the model outcome, while oblique has factors that are correlated to one another (Knekta, Runyon & Eddy, 2019). This study employed the orthogonal varimax technique. Thompson (2004) argues that this is the most popularly used technique in FA under rotational methods. The second reason for using it was that it produces factor structures that are uncorrelated (Costello & Osborne, 2005).

Step 5 – interpretation and labelling of factors

Rotational method tends to group or cluster variables under specific factors. Most of the factors extracted in this study had at least two or more clustered variables loading onto it. Thus, an appropriate or suitable theme had to be identified and then label the factor with a construct or single name that could as much as possible reflect the theoretical and conceptual intent of the variables forming it. According to Henson and Roberts, 2006, meaningful interpretation of a factor takes place if at least two or three variables could be loaded on that factor. Thus, when the factors are taken together, they can explain the majority of the responses of the participants. Taherdoost, Sahibuddin & Jalaliyoon, (2014) define interpretation in factor analysis as an examination process intended to select variables attributable to a construct and labelling the construct as well. Thus, interpretation in a nutshell focuses at giving meaning to the cluster of variables attributed to a factor. In this study, the final stage of the data analysis process, for the questionnaire quantitative data, was identifying a construct associated to a factor, and labelling it with an appropriate name, to reflect the intent of the clustered variables.

3.3.2.6 Analysis of qualitative data from the SALG survey instrument

The data analysis process involved transcribing students' explanations. These transcriptions were read several times in a row to gain an understanding of what students thought they had gained during the implementation of the intervention. The analysis of data was done following how the instrument is structured. It has two mains parts namely (1) learning goals- which is covered by 4 key questions focusing on *understanding, skills, affective gains, and integrations (or habits)*, and (2) pedagogy- which is covered by six key questions focusing on *course design, class activities, graded assignments, resources, meta-information, and support for the individual learner*.

According to Burnard et al, (2008), a pragmatic approach may be used to analyse qualitative data. The analysis may be deductive or inductive in nature. The deductive approach uses a predetermined framework to analyse data, where the researcher imposes a structure on the data collected and the analysis must follow this structure. Alternatively, the researcher may use an inductive approach to analyse the qualitative data. There is no predetermined theory or structure, or framework involved this case, but the data itself is used to come up with a structure for analysing it. Each of these approaches has its own strengths and limitations. The deductive approach is most useful in cases where the researcher is aware of participant responses such that the analysis may lead to determination of the number of participants identifiable with a particular response. The approach is thus relatively quick and easy. However, its limitations include inflexibility leading to bias for specific responses. Thus, development of themes and theory becomes hindered as the researcher works within a rigid framework. On the other hand, the inductive approach provides the researcher the opportunity to generate new themes. The inductive approach suits cases where little or nothing is known about the phenomenon.

In this study the deductive quantitative data analysis approach was used considering the large size of data needed to be analysed. An easier approach was needed to cover the analysis in a shorter time, unlike the inductive approach which is time-consuming. To reduce bias, the deductive approach adopted for this study permitted, besides the predetermined structure of codes, emerging new codes, or themes to be formulated if they could not fit within the predetermined structure. The same approach to data analysis was used in all micro-phases from 2015 to 2019.

3.3.3 Interview Protocol

In terms of academic study, an interview may be a way of collecting information or data by a researcher, in which the researcher asks questions to the respondent and records the answers supplied by the respondent as well. There are three types of interviews that may be conducted, namely: a structured interview- in which the questions are mostly closed-ended questions, providing response options to interviewees; semi-structured interview- consisting of a series of open-ended questions based on topic areas of interest to the researcher and what he / she wants to cover; and the unstructured or in-depth interview- in which there is very little structure. Questions are framed according to interviewee's previous response. Few topics are covered, may be one or two but in great detail. This study used the semi-structured interview.

The interview guide consisted of 10 open-ended questions (see appendix F). The questions sought information on how students characterised the; content they engaged in (question 1), development of cognitive skills (question 2), impact on their learning of the out of class learning environment (question 3), impact of the in-class learning environment (question 4), level of demand at which the course was pegged/delivered (question 5), impact on their learning of the video content/lectures (question 6), impact of FCA in preparing students for the final semester examination (question 7), limitations of FCA (question 8), content organisation to facilitate understanding (question 9), and laboratory activities (question 10).

3.3.3.1 Validity of the interview guide

The questions were prepared in advance. There was no pilot study used to refine the questions as such, but the protocol was given to other senior academics for their opinions so that they could examine if the questions were measuring the intended face, content, or construct validity. The academics assured that the questions asked were relevant to the purpose of the guide. The interview was meant to assess the effectiveness of the implementation of designed intervention in relation to four major areas of the course delivery process, namely: (1) preparation of students for in-class activities using pre-recorded video lectures, (2) in-class discussions where students were provided with learning tasks designed to improve their conceptual understanding of geometrical optics, (3) the post-class activities that were meant to consolidate learning that took place during the in-class sessions, and (4) the assessment activities to which students were subjected. The feedback received from the consulted academics identified flows on how the question items addressed each of the four areas indicated above. They helped identify how the various questions on the guide addressed the four areas of concern, and the extent to which they did so. Where questions were found wanting, they recommended them to be deleted. They also assured that the questions were not biased in any way but remained neutral. In addition to these indications, they also checked on structural aspects, such as if the question was confusing to the reader or not, grammatically correct, or not, whether language used took into consideration that the student participant was a second language speaker in terms of the English language (Elangovan & Sundaravel, 2021; Taherdoost, 2016)

3.3.3.2 Reliability of the interview protocol

The reliability of the interview guide was assured by making use of the suggestions provided by Alshenqeeti (2014, p. 44). The suggestions were that (1) the interviewer should avoid asking leading questions., (2) the interviewer should record the interview and take notes as well rather than depending on recordings only, (3) there researcher should conduct a pilot interview, and (4) to give the interviewee a chance to sum up and clarify the points they have made. Reliability is understood to refer to the extent to which an instrument yields same results on repeated trials. Among these four situations that can be carried out to improve the reliability of an interview instrument, it has already ben pointed out that the study did not carry out a pilot interview.

However, the other three suggestions were implemented. (Brewerton & Millward, 2001) pointed out that interviews are open to bias, and because of this, leading questions should be avoided as such a strategy serves to promote bias. As such the interview questions were framed in a neutral way, except in cases where the participant showed a great difficulty in understanding the question, or in cases where the researcher suspected the interviewee to be holding information (Cohen, Manion & Morrison, 2018). Questions were carefully formulated so that participants had clear meaning of what they were being asked for, with further explanations where it was deemed necessary. The questions asked to each of the participant were the same. Participants were also provided the opportunity to elaborate their views as part of ensuring reliability of the interview instrument used.

3.3.3.3 Data collection procedure using the interview protocol

Among some of the strategies used to conduct interviews are the face-to-face interview-which is used when subject matter is sensitive, when questions are complex, or lengthy; the telephone interview- used where the sample is accessible via the telephone, and the focus interview-used to collect information from a group of people.

This study used a semi-structured interview, because the open-ended nature of the questions provided opportunities to both the researcher (interviewer) and respondent (interviewee) to discuss in much more detail, areas that were not clear to the researcher (Mathers, Fox, & Hunn, 1998; Fox, 2009). Open-ended questions enable the researcher to capture as much information as possible from the respondents. In this study, the researcher used cues or prompts in areas where the respondents were experiencing difficulties in answering a question, or in cases where the response provided was brief. The cues or prompts encouraged respondents to provide more information in addressing the question. As participants elaborated their original responses, the researcher would pursue a line of inquiry to get information. However open-ended questions tend to increase the amount of time required to analyse the interview data. To mitigate against this drawback, only eleven students were selected to take part in the interview, based on how they performed academically. The students were selected from high, average, and low achievers. The participants were informed and invited in advance before the date of the interview, and all agreed to participate voluntarily. For purposes of identification, the participants were identified as participant1 to participant 11, and the year in which the participant was interviewed is also included, such as $P1_{2016}$.

The period in which all data used in this study was collected was from 2015 to 2019. However, no interview was conducted in 2015 as the intervention was still under design, and the interview guide was part of the instruments under design. Thereafter, three student participants were interviewed in 2016, four in 2017, four in 2018, to make a total of eleven. No interview was conducted in 2019. Each interview lasted at least half an hour.

3.3.3.4 Analysis of interview data

The interview guide comprised of ten semi-structured questions, of which students were asked to provide their opinions according to their learning experiences. Each question sought specific information from the participant. The interview data analysis was about making sense of participants' learning experiences of their learning situations. According to Cohen, Manion & Morrison (2018), qualitative analysis involves noting patterns, themes, categories regularities and irregularities in the data collected. There is no one way of conducting this process since multiple interpretations are possible. This study followed the steps indicated in the paragraphs below.

The first step involved transcribing data recorded on audio tapes into word format. Micro-Soft Office 365 was used since it has voice recognition software and can recognise and transcribes speech. The transcription was thereafter edited since it contained inaccuracies. These inaccuracies were due to Micro Soft Office 365's speech recognition ability being unable to transcribe accurately some of words on the audio speech it received. Some of the words were not clear hence inaccurately translated.

The second step involved examining the information on each script according to the questions on the interview guide. There were ten questions from which participants' opinion were sought. Question: (1) was about the level of demand of the content experienced, (2) how students perceived the instructional approach in general, whether they were in favour of it or not, (3) after class activities-how students interacted among themselves and with the instructor, (4) in-class activities-how they benefited from them, (5) the active learning strategies employed in class, (6) teaching and learning materials employed, (7) Exam preparation after instruction, (8) weaknesses of the instructional approach employed, (9) organisation or sequencing of the content's key ideas that were taught, and (10) the laboratory activities employed. The information under each question was broken into categories.

The third step was grouping similar categories into another single category come up with a theme, while the last stage was comparing categories looking for linkages or contrasts between them.

The procedure for analysis of the qualitative data from the interviews was the same for all cohorts. All the tapes of the interviews were transcribed so that they could be examined. A content analysis was then carried out to identify the key concepts followed by categorisation and development of common themes.

3.4 ETHICAL CONSIDERATIONS

According to Tichapondwa (2013), there are three stages in which ethical considerations appear in a research project, namely-at the time of recruiting participants, during the implementation of an intervention or the process of data collection, and finally in the release of the results. In order to avoid infringing on ethical considerations of the participant, it becomes imperative therefore to pay attention to the following issues: informed consent, confidentiality and anonymity, plagiarism, and protection from physical and psychological harm. At the time of recruiting participants, the participants were students enrolled in a normal university program and had been recruited into the program following the normal university process for recruiting student. Thus, the method was not considered in any way harmful to the participant. During the implementation of the designed prototype interventions, the designed intervention was considered as part of a teaching techniques or strategies that an instructor may employ to improve performance in an educational set up. Just like in a traditional method, the approach was not considered to be harmful as all educational materials involved and classroom activities had to go by the normal educational code of conduct. Students' permission was sought through signing of consent forms were necessary such as at the time of interviews. Students were informed that their names were in no way to be revealed in the report, and the recordings made during interviews would remain under lock until such a time they can be permanently disposed. Permission at the site of research (university concerned) was also sought through the gatekeeper permission before the study was conducted. An attempt was made as much as possible to avoid plagiarism throughout the writing of the report by making use of relevant supervisory mechanisms such as the supervisor herself. Students were subjected to the same teaching strategy to avoid creating situations where some students would feel they benefited more if they were treated differently, which could lead to psychological issues among those treated otherwise. To provide evidence that all ethical conduct was adhered to, an ethical clearance application was submitted to the institution where the study was conducted, and permission was granted (see appendix C).

3.5. SUMMARY OF CHAPTER 3

This chapter described the methods used to answer the research questions in this study. A design-based research methodological framework was used to guide the research procedure. The entire process of collecting data was divided into three main phases consisting of a preliminary research phase, prototyping phase, and assessment phase. Details of what was involved at each phase were fully provided. Five student cohorts were involved in this study, from 2015 to 2019. Each cohort was regarded as a micro-study of its own, with its own participants from which data was collected and analysed. The results or finding of each micro study were used to improve the intervention used with subsequent groups. All participants were pre-service teachers in their third year of study, training for a Bachelor of Education degree in Science Education. Both quantitative data and qualitative data were collected using three instruments, the LOCE, SALG and Interview. Details of how each method was employed were provided. In chapter 4, the findings of the study are presented according to each micro study.

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.1. INTRODUCTION

This chapter presents results of the analysis of the data collected in all micro studies conducted in this study, as well as results of the analysis of data collected to test the effect of implementing the designed intervention. The results are discussed under six main sections, starting from section 4.2.

The first of these six sections (see section 4.2) provides quantitative and qualitative results of the SALG survey instrument for the pilot group of 2015. The 2015 SALG was not the same as the one used in the 2016 to 2019 groups (SALG survey-instrument). The reason being that the 2015 student cohort was a pilot group used to modify the instruments. The second section (see section 4.3) provides data analysis and results of the micro study conducted in 2016. The instruments from which data were collected were the SALG survey instrument, which is part quantitative and part qualitative, and the interview protocol (see Appendix D and Appendix G). The third (see section 4.4), fourth (see section 4.5) and fifth (see section 4.6) sections provide data analysis and results, for micro studies of 2017, 2018 and 2019 respectively, using the same instruments (see Appendix D and Appendix G). The sixth (see section 4.7) provides data analysis and results on effectiveness of the intervention.

Quantitative data from the SALG survey instrument was analysed using Factor Analysis (FA) method, using SPSS version 26. The purpose of using factor analysis was to explore the factors that had an impact on student learning at each micro study level. FA was conducted on all student cohorts of 2015 to 2019.

Qualitative data from the SALG survey instrument was analysed using thematic content analysis. The purpose was to identify themes which had strong influence on student learning during the implementation of the intervention.

The qualitative data from the interview was analysed using narrative analysis. The data was used to highlight main educational aspects in themes identified. Thus, data were used as relatable perspectives, providing quotes supporting themes identified through the analysis of responses to the open-ended questions of the SALG survey instrument.

The sixth section provides results for the LOCE instrument used to measure prior and post-performances of students conceptual understating of geometrical optics. There were five groups of students that were taught using FCA instructional strategy. At each group level, the FCA instructional strategy was adjusted based on comments from the preceding group of participants' that was taught in the year before using the same instructional strategy. The first group to be taught using FCA was the 2015 student cohort. The group was not subjected to a pre-post-test but was taken as the piloting group that helped to modify the initial design of the FCA instructional strategy, as well as the designing of the questionnaire (SALG) instrument used in this study. The second group to be subjected to the FCA instructional strategy was the 2016 student cohort. This group did not take a pre-test but only a post-test due to circumstances beyond the control of the researcher. However, the group's inputs were used to inform the adjustments made for the 2017 FCA instructional strategy. The same mechanism of adjusting the instructional strategy was used for the subsequent groups of student cohorts of 2018 and 2019. Comparison analysis of academic performances was done with groups of 2017, 2018 and 2019 using One Way ANCOVA in SPSS version 26.

4.2 FINDINGS FROM THE PILOT STUDY OF 2015

4.2.1 Quantitative results from the SALG survey of 2015

4.2.1.1 Profile Data of Respondents

This was the first study conducted in 2015 in which there were 63 participants, with 23 (36.5%) of them being females and 40 (63.5%) males as shown in Table 4.1. The study had therefore more males than females.

Table 4. 1: Demographic profile of respondents

Variable	Category	Frequency (N)	Percentage (%)
Gender	Female	23	36.5
	Male	40	63.5
	Total	63	100.0
Age	18-19	1	1.6
	20-21	28	44.4
	22-24	26	41.3
	25 and above	8	12.7
	Total	63	100.0

The majority of the respondents came from the age groups of 20-21 (44.4%) and 22-24 (41.3%) while a few 8 (12.7%) were 25 years old and above. Only 1 (1.6%) student was within the 18–19-year age group.

4.2.1.2 Reliability Analysis

A reliability analysis was conducted on the questionnaire comprising of 50 items. Cronbach's Alpha (α) was found to reach an acceptable value of α = .927. Most of the items had high alpha values which could decrease if they were removed. An exception was found to be with five items where the alpha value would increase to α = .936 if they were removed. These items were 16, 17, 18, 22 and 26. As such the five items were removed, retaining 45 items of the initial 50. The Cronbach's Alpha test was .936 indicating high internal consistence of data and its validity for factor analysis.

4.2.1.3 Suitability of Data for Factor Analysis

The data was tested for its feasibility for factor analysis by calculating the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett Test. If the sampling is found to be more than 0.5, one can proceed to conduct adequate factor analysis (Hair *et al.*, 1998). The value of KMO was found to be .584 and the Bartlett's test of Sphericity had a Chi Square value of 1934.977 with significant value 0.000 as shown in Table 4.2.

Table 4. 2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.584
Bartlett's Test of Sphericity	Approx. Chi-Square	1934.977
	df	990
	Sig.	.000

4.2.1.4 Factor Extraction

From a total of 45 variables (i.e. items on the questionnaire) analysed, 13 variables had Eigenvalues of 1 or above, accounting for 75.9% of the variance. Table 4.3 shows the 13 variables whose Eigenvalues were greater than 1 and a cumulative percentage value of 75.9% of the variance. These variables are identified as components in the first column of the Table 4.3. Thus, according to the Eigenvalue criteria there are 13 major themes or underlying latent factors that can be identified from this data.

Table 4. 3: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.59	27.98	27.98	12.59	27.98	27.98	3.88	8.62	8.62
2	3.15	6.99	34.97	3.15	6.99	34.97	3.75	8.34	16.96
3	2.70	6.00	40.97	2.70	6.00	40.97	2.93	6.52	23.48
4	2.29	5.08	46.06	2.29	5.08	46.06	2.74	6.10	29.58
5	2.23	4.95	51.01	2.23	4.95	51.01	2.74	6.10	35.67
6	1.82	4.05	55.05	1.82	4.05	55.05	2.73	6.07	41.74
7	1.61	3.59	58.64	1.61	3.59	58.64	2.63	5.84	47.58
8	1.57	3.49	62.13	1.57	3.49	62.13	2.60	5.77	53.35
9	1.38	3.07	65.19	1.38	3.07	65.19	2.59	5.75	59.09
10	1.32	2.92	68.12	1.32	2.92	68.12	2.56	5.68	64.78
11	1.25	2.78	70.90	1.25	2.78	70.90	1.75	3.90	68.67
12	1.20	2.66	73.56	1.20	2.66	73.56	1.64	3.64	72.31
13	1.06	2.35	75.91	1.06	2.35	75.91	1.62	3.59	75.91

4.2.1.5 The Scree Plot

The number of components extracted using the Eigenvalue criteria described above was further verified by conducting the Scree Plot test as shown in Figure 4.1. The Scree Plot shows the Eigenvalues plotted against all the 45 variables in the questionnaire. According to the Scree Plot criteria, the number of principal components extractable from the data correspond to the number of plots that lie above the horizontal line drawn passing through the value of 1 on the Eigenvalue axis. Alternatively, a straight line can be drawn from the right end of the graph, through all the plotted points to a point where the graph starts to curve upwards. The number of remaining points not covered by the straight line are considered to represent the number of principal components or underlying latent factors being sought.

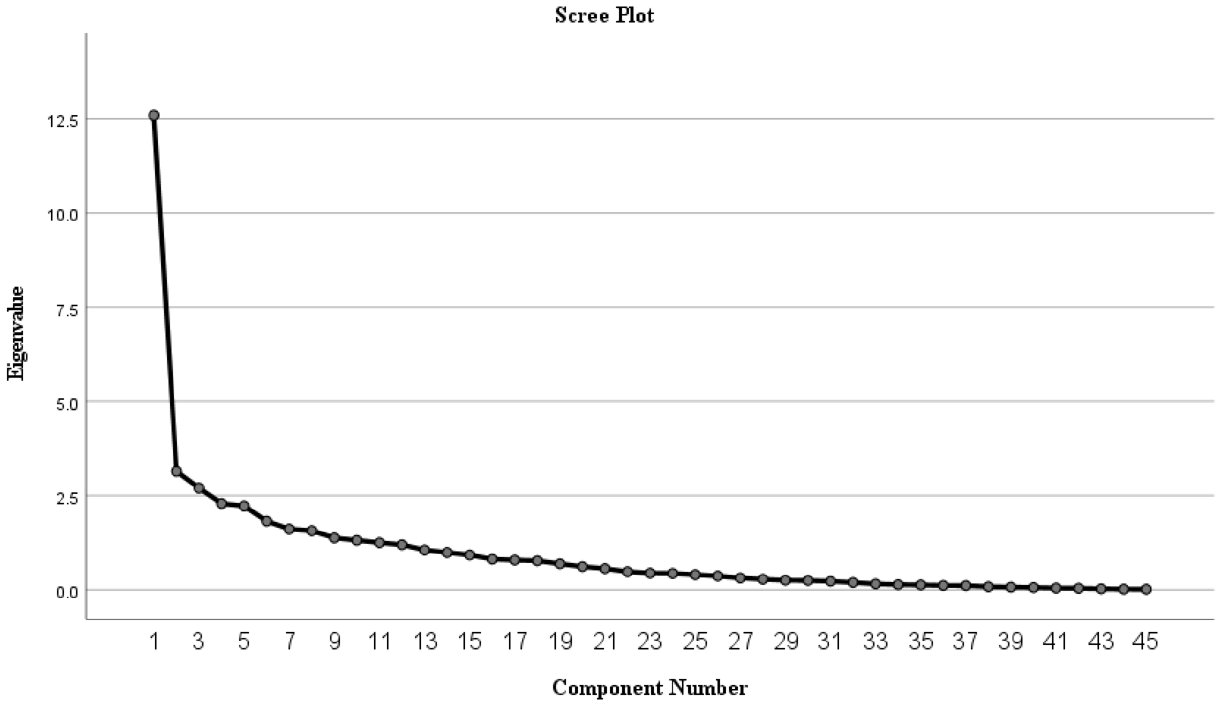


Figure 4. 1: Number of components extractable from the set of 45 variables.

4.2.1.6 Naming the Factors

Table 4.4 shows all 13 factors extracted from the 45 variables subjected to FA. The factors are listed from one to thirteen in the first column while the second column shows a cluster of variables that loaded highly on a particular factor. This cluster of variables was used to identify the underlying theme from which the name given to the factor was obtained from. In Table 4.4 the cluster of variables were placed in the column with the heading Factor Attributes. In order to come up with meaningful names for the factors, the top one or two loading items for each factor were used, as these items load highly onto that specific factor. In Table 4.4 the top loading item on factor 1 was '*the main concepts explored in this class*' (.775). Thus Factor 1 was associated with exploration of key concepts, hence was named *exploration of key ideas*. Similarly, the other twelve factors were named using the same technique. Some factors such as the last three factors, 11, 12 and 13 share the same underlying theme with factors 3 and 9, and as such the same name for Factors 3 was given to Factor 11 and 13, while that of Factor 9 was given to Factor 12.

Table 4. 4: Names of factors (derived from attributes and factor loadings) that influenced learning in participants of 2015

Factors & their names	**Factor attributes**	**Factor Loadings**
Factor 1	The main concepts explored in this class	.775

Exploration of key geometric optics ideas	The pace of the class-i.e., time interval between activities	.752
	Confidence that you understand the material	.574
	Developing a logical argument	.573
	How ideas from geometric optics relate to ideas encountered in other classes within physics	.541
	The relationships between the main concepts	.514
	Opportunities for in-class review given by the instructor	.465
	Interacting with the instructor during the class	.434
	Explanation given by the instructor of how to learn or study the material	.405
Identifying and exploring key ideas in geometrical optics used to develop logical arguments, interrelating them with other physics ideas: mean = 0.559		

Factor 2 Participation in class discussions	Participating in discussions during class	.828
	Listening to discussions during class	.818
	Working with peers during class	.677
	Participating in group activities during class	.609
	Attending lectures	.573
	Working effectively with others	.521
Employing strategies that promote active participation during class discussions: mean = 0.671		

Factor 3 Self-confidence to take charge of own learning	Enthusiasm for the subject	.708
	The way the grading system helped me understand what I needed to work on	.670
	Preparing and giving oral presentations	.490
	Critically reading materials after lesson about issues raised in class	.445
Providing feedback on graded activities motivating students to be prepared to make oral presentations in class and critically read materials after class: mean = 0.578		

Factor 4 Use of evidence-based arguments	Identifying patterns in data in laboratory activities	.815
	Recognising a sound argument and appropriate use of evidence	.799
	Finding material relevant to answer a particular problem from different sources	.537
Encouraging students to use evidence-based reasoned arguments: mean = 0.717		

Factor 5 Use of graded activities	Graded assignments	.762
	Graded group activities	.587
	Writing documents (e.g., lab report) in discipline appropriate style and format	.537
	How the class topics, activities, and assignments fit together	.503
Promoting the use of formative graded activities that are in line with key ideas taught: mean 0.597		

Factor 6 Practical implications of theory studied in class	How studying geometric optics helps people address real world issues	.782
	Applying what I learned in geometric optics in other situations	.566
Incorporating real-life implications of theory studied in class: mean 0.674		

Factor 7 Interconnectedness of scientific ideas	Connecting key class ideas with another knowledge	.784
	Interest in discussing the subject area with friends or family	.500
	Using a critical approach to analysing data and arguments in my daily life	.451
	Interacting with the instructor during office hours	.435
Encouraging reasoning, based on key ideas studied in class, beyond the classroom: mean 0.542		

Factor 8 Collaborative work	Willingness to seek help from others (lecturer. Peers, etc.) when working on academic problems	.834
	Video resources used to deliver new content before class time	.672
	Doing hands on classroom activities	.558
Providing video-based activities, on time, in support of class discussion activities: mean 0.688		

Factor 9 Organisation of learning activities	The number and spacing of the tests	.719
	The time between class content and tests	.711
	Using systematic reasoning in my approach to problems	.533
	The mental stretch required by tests (cognitive demand of tests)	.473
Considering time, and cognitive demand when planning for content delivery and grading activities to allow a systematic reasoned approach to solving problems: mean 0.609		

Factor 10 Instructional strategies	The instructional approach taken in this class	.763
	How ideas from geometric optics relate to ideas encountered in classes outside physics	.702
Allowing students to interrelate key geometrical optics ideas to other scientific ideas: mean 0.733		

Factor 11 Self-confidence to take charge of own learning	Interest in taking or planning to take additional classes in this subject	.754
Developing interest in the subject allowing students to take charge of their own learning: mean 0.754		

Factor 12 Organisation of learning activities	Explanation of how the class activities, assignments and lab activities are related to each other.	.847
Showing students how different activities they are involved in are interrelated: mean 0.847		

Factor 13	Confidence that you can do geometric optics	.687

Self-confidence to take charge of own learning	Your comfort level in working with complex ideas	.563
Developing confidence in students allowing them to take charge of their own learning: mean 0.625		

In summary, the key factors that influenced student learning were those associated with:

1. Identifying and exploring key ideas in geometrical optics used to develop logical arguments, interrelating them with other physics ideas.
2. Employing strategies that promote active participation during class discussions.
3. Providing feedback on graded activities motivating students to be prepared to make oral presentations in class and critically read materials after class.
4. Encouraging students to use evidence-based reasoned arguments.
5. Promoting the use of formative graded activities that are in line with key ideas taught
6. Incorporating real-life implications of theory studied in class.
7. Encouraging reasoning based on key ideas studied in class beyond the classroom.
8. Providing video-based activities on time in support of class discussion activities.
9. Considering time, space, and mental stretch when planning for content delivery and grading activities to allow a systematic reasoned approach to solving problems.
10. Allowing students to interrelate key geometrical optics ideas to other scientific ideas.
11. Developing interest and confidence in the subject allowing students to take charge of their own learning (combining factor 11 and 13).
12. Showing students how different activities they are involved in are interrelated.

The above summary of factors or ideas are considered in this study to have greatly influenced the learning of geometrical optics concepts by student participants.

4.2.2 Qualitative results from the SALG survey of 2015

The SALG survey instrument that was used to generate quantitative data (see section 4.2.1) had 13 open-ended questions. Participants were asked to openly express their views without being confined to given options. The open-ended questions were as follows:

1. Please comment on how the instructional approach to this class affected your learning.
2. Please comment on how this class influenced how you study? Please explain
3. Please comment on how the class activities influenced your learning
4. Please comment on how the graded activities and tests influenced your learning

5. Please comment on how the video resources in this class influenced your learning
6. Please comment on how other material other than videos (textbooks, online material, etc.) used in this class influenced your learning
7. Please comment on how the information you received about the class influenced your learning
8. Please comment on how the support you received from others influenced your learning in this class
9. Please comment on how your understanding of geometric optics has changed as a result of the class content
10. Please comment on how the way the content was taught influenced your recalling of key ideas
11. Please comment on what skills you have gained as a result of this class
12. Please comment on how this class influenced your attitude towards this subject.
13. What will you carry with you into other classes or other aspects of your life?

This section provides an example of how data associated with each of the questions listed above was analysed, by focusing on data from question one. Question one was also chosen as an example because it provided participants the opportunity to give an overview about the entire learning experience, unlike the other questions which are more specific on certain aspect of learning. There were 93 participants in the pilot study. Question one was answered by 56 students. There were 49 (88%) participants whose responses were positive sentiments about how the instructional intervention or approach was implemented, while only 7 (12%) expressed some reservations about how the same intervention was implemented. The analytical process of the data for this question involved firstly compiling all participants' responses in a single table. Secondly, the main idea from each statement was extracted in form of short phrases and listed separately. Thirdly, the listed ideas were grouped into two main categories- Positive sentiments and negative sentiments. The fourth step was to group similar ideas together to form another new category or a theme of their own. The process was lengthy, so all the steps could not be shown in this section. Only the main ideas identified from participants' responses are provided as findings related to question one.

Strengths of the intervention

Some of the students provided general statements about how the instructional approach affected their learning. Their view was that the instructional approach was useful, made learning of concepts easier, was the best learning experience they had ever had, improved their ability to learn things, and as a result they appreciated the employment of this strategy. The specific issues considered to be the strength of the intervention according to students' perceptions were:

- The instructional approach enabled students to take charge of their own learning
- The instructional approach provided opportunity for every participant to participate in all learning activities
- Discussions in class promoted a deeper understanding of concepts or promoted learning with understanding
- Videos could be replayed to facilitate recall of facts and concepts, hence made learning easier
- Watching videos before class enabled students to prepare for the in-class activities
- There was a lot of collaboration among students when solving problems through group work
- The lecturer provided clear instructional guidance and explained content clearly, this helped a lot to understand the content
- Demonstrations conducted by the lecturer made it easier to understand the concepts.
- The approach keeps students busy or occupied always
- The physical environment or classroom environment was more of a workshop where students did more of the activities than the instructor himself.
- The approach created more time for learning
- The content was related to real-life situations
- Assessment tasks were demanding and challenging

Weaknesses of the intervention

The issues students expressed as weaknesses of the intervention were:

- The approach was good for more capable students.
- Activities before the in-class session were poorly assessed because videos were watched without immediate assessment to check whether students were understanding the uploaded material.
- Students were inundated with work, but less time was available to assimilate it.
- There was more content to be covered but less time available
- During the in-class sessions, the lecturer had minimum work while students had more
- The physical environment was not supportive of the instructional approach employed because of the large number of participants involved.

- Not all concepts were covered and understood by student participants.
- There were no adequate learning materials other than video materials that were provided to students by the instructor
- Most activities were centered on individual or collective (group) work rather than conducting proper lectures in class.
- Depth of content on videos did not match the high standard of assessment employed -where questions were pegged at higher cognitive levels.

The findings show that the positive perceptions are the advantages of using the intervention or strengths of the intervention, while the negative perceptions are the disadvantages associated with the use of the intervention, or the weaknesses of the intervention. During implementation of the subsequent interventions, there was always an attempt to address the weaknesses of the intervention, unless the issue was beyond the control of the instructor. To cite an example, issues like - *the physical environment was not supportive of the instructional approach employed because of the large number of participants involved*. A class of more than seventy students, discussing high cognitive level problems, may be difficult for an instructor to attend to individual student needs, even though group discussion, as a strategy, may be used for the students to share their individual problems. Such a problem was beyond the control of the instructor.

A similar approach to analysis of participants' responses was conducted with the rest of the other twelve questions. On combining all findings from the thirteen questions led to regrouping of items that had the same underlying theme. Eight themes were identified from participants' responses, namely issues related to: understanding the content (see question 9), how assessment was carried out (see question 4), how videos affected their learning (see question 5), how the feedback was provided (see question 4), how class discussions were conducted (see question 3), how the instructor guided the students (see question 7), instructional approach in general (see question 1), how materials other than videos helped students (see question 6), role of the lecturer (see question 8) , and how after class activities benefited the students (see question 8). Thus, the questions helped to come up with themes indicated in Table 4.5. In order to compare how each theme was frequently mentioned by participants within the same and across questions, Table 4.5 was constructed. It shows a summary of the ten themes that emerged from the responses of the open-ended questions. Not all of the participants gave responses to each of the thirteen open-ended questions. The count for each theme was done according to the number of times the idea appeared in all texts generated from a particular question. Thus, the count was not done as per number of students who raised the idea, as some students would raise more than one idea in the same text.

Table 4. 5: Educational themes and frequency of responses from open-ended questions of 2015

Code	Theme- Issues related to:	q1 Count	q2 Count	q3 Count	q4 Count	q5 Count	q6 Count	q7 Count	q8 Count	q9 Count	q10 Count	q11 Count	q12 Count	q13 Count
1	Content	8 (14%)	-	18 (27%)	11 (17%)	20 (30%)	20 (31%)	9 (15%)	8 (12%)	25 (39%)	12 (19%)	4 (7%)	19 (33%)	29 (41%)
2	Assessment	2 (4%)	-	9 (13%)	11 (17%)	-	2 (3%)	4 (7%)	2 (3%)	-	-	-	-	2 (3%)
3	Videos	19 (33%)	34 (65%)	2 (3%)	1 (1%)	28 (42%)	17 (26%)	2 (3%)	-	5 (8%)	19 (30%)	2 (3%)	7 (12%)	10 (14%)
4	Feedback	-	-	1 (1%)	27 (41%)	-	-	-	-	-	-	-	-	-
5	Class discussions	5 (9%)	-	29 (43%)	2 (3%)	2 (3%)	1 (1%)	5 (9%)	21 (31%)	3 (5%)	8 (13%)	41 (67%)	21 (36%)	10 (14%)
6	Guidance	2 (4%)	-	1 (1%)	2 (3%)	-	2 (3%)	33 (57%)	15 (22%)	-	2 (3%)	-	-	6 (9%)
7	Instruction	14 (24%)	2 (4%)	-	-	9 (14%)	-	1 (2%)	-	7 (11%)	10 (16%)	-	2 (3%)	6 (9%)
8	Other learning materials	-	6 (12%)	-	-	6 (9%)	20 (31%)	1 (2%)	-	-	-	-	1 (2%)	4 (6%)
9	Lecturer	-	-	-	-	-	-	2 (3%)	11 (16%)	1 (1%)	10 (16%)	-	1 (2%)	-
10	Collaborative work	7 (12%)	10 (19%)	-	12 (18%)	1 (2%)	3 (5%)	1 (2%)	11 (16%)	23 (36%)	2 (3%)	14 (23%)	7 (12%)	3 (4%)
Total Counts		57 (100%)	52 (100%)	68 (100%)	66 (100%)	66 (100%)	65 (100%)	58 (100%)	68 (100%)	64 100%)	63 (100%)	61 100%)	58 100%)	70 (100%)

Table 4.5 is a summary of how strongly students felt about one theme as compared to the other themes. It enables an examination of how many times a theme was mentioned within the same question as well as across different questions as indicated in the following paragraphs:

For question one (q1): *Please comment on how the instructional approach to this class affected your learning*- An examination of how many times a theme was mention compared to the other nine themes, within the same question (inspection down the same column) shows that participants talked more about videos (33%) as having the greatest influence on their learning, followed by instructional strategies (i.e., interactive learning activities designed for the acquisition of skills or knowledge) (24%) and collaborative work (12%). Thus, learning appears to have been strongly influenced by videos, instructional strategies, and collaboration among the participants.

For question two (q2): *Please comment on how this class influenced how you study? Please explain*. There were two themes representing educational aspects that mostly influenced how participants were studying the subject material. These were videos (65%) and collaborative work (19%).

In question three (q3): *Please comment on how the class activities influenced your learning,* the highest frequency of appearance was the influence of class discussions (43%). The second strongest theme was about issues related to understanding of the content (27%), while the influence of assessment was reasonably high (13%).

Question four (q4): *Please comment on how the graded activities and tests influenced your learning*. The strongest theme that came out as influencing learning was issues related to feedback (41%). The other two themes that came out but less mentioned were issues related to understanding of content (17%) and issues related to assessment (17%).

Question five (q5): *Please comment on how the video resources in this class influenced your learning*, was about how videos impacted participants' learning. Three factors that emerged with strong influence were videos (42%), issues related to content (30%) and instructional strategies (14%).

Question six (q6): *Please comment on how material other than videos (textbooks, online material, etc.) used in this class influenced your learning*. Two themes came out much stronger than the rest namely issues related to understanding of the content (31%) and issues related to materials other than the videos (31%). These two were followed by videos (26%).

Question seven (q7): *Please comment on how the information you received about the class influenced your learning*. Information here is regarded as knowledge communicated. In table 4.23, only two themes appear to be stronger compared to others. These are the influence of guidance (or orientation, 57%), followed by issues related to understanding of content (15%).

Question eight (q8): *Please comment on how the support you received from others influenced your learning in this class*. Four themes standing out were the influence of class discussions (31%), guidance (22%), lecturer (16%) and issues related to understanding of content (12%).

Question nine (q9): *Please comment on how your understanding of geometric optics has changed as a result of the class content*. Participants talked more about issues related to understanding of content (39%), the influence of collaborative work (36%) and instructional strategies (11%).

Question ten (q10): *Please comment on how the way the content was taught influenced your recalling of key ideas*. Five themes were mentioned more than others. These were influence of videos (30%), issues related to understanding of content (19%), influence of - instructional strategies (16%), lecturer (16%) and class discussions (13%).

Question eleven (q11): *Please comment on what skills you have gained as a result of this class*. This question had two most outstanding themes that were mentioned, namely influence of class discussions (67%) being the highest, and secondly collaborative work (23%).

Question twelve (q12): *Please comment on how this class influenced your attitude towards this subject.* This question had four out of ten themes mostly mentioned. These were influence of class discussions (36%), understanding of content (33%), influence of videos (12%) and collaborative work (12%).

Question thirteen (q13): *What will you carry with you into other classes or other aspects of your life:* On this question, three themes mostly mentioned were issues related to understanding of content (41%), influences of videos (14%) and class discussions (14%).

Table 4.6 is part of Table 4.5 but the two could not be collapsed into one because of the nature of the question participants had to answer. The question addressed by Table 4.6 sought participants' opinion on classroom situation in terms of whether it was conducive for learning, and how often then they participated in activities that were taking place. Most of the opinions (42%) showed participation was high and encouraging while a small proportion of the counts showed neither encouraging nor discouraging, thereby it could not be identified how often the participants participated in the discussions that ensued in the class. The first three aspects in the table concur that the atmosphere was encouraging though they differ in frequency of participation of the participants. Thus, in total they show 72% of the responses were in favour of an encouraging atmosphere in the classroom, while a 25% of the responses did not consider the atmosphere as encouraging learning.

Table 4. 6: Comments related to classroom atmosphere for the pilot group of 2015

Code	Please comment on: a. How often you participated in class discussions? b. How the atmosphere in the classroom encouraged or discouraged your participation?	Count	(%)
1	Low but encouraging	11	18
2	Moderately but encouraging	7	12
3	High and encouraging	25	42
4	Low and discouraging	15	25
5	Neither encouraging nor discouraging	2	3
TOTAL COUNTS		60	100

The words low, moderately, and high are addressing the first question (a) in Table 4.6, while discouraging is addressing the second question (b) in the same Table 4.6.

Information in Table 4.6 was used to improve the design of the intervention. According to information in this table, the atmosphere in the class was considered to be mostly encouraging (42%). This category had the highest count in terms of how students strongly felt about each category. The nature of the class discussions involved group discussions, whole class discussions, and group presentations. These strategies were therefore incorporated always incorporated in the design of instruction in all groups during the implementation of the intervention. In the majority of the discussions (72% - summing up the first four items in the table), the atmosphere was encouraging, even though a few students mentioned their participation was low (18%) and moderate (12%). The findings revealed that the strategies that were employed during class discussions encouraged student participation in all exercises and debates that were taking place. Students felt much more comfortable in dealing with complex tasks when engaged in peer discussions and cooperative work. There were a few who mentioned their complete discontent with the approach taken in class (25% of the counts). To accommodate this group of students, students were always encouraged to raise their discontent about the class proceedings by introducing a suggestion box kept by the entrance, thereby providing the opportunity to drop written opinions into the box, and anonymously removing the fear of communicating with the instructor.

4.2.3 The interview results from the study of 2015

No interviews were conducted with this student cohort since both the intervention and the SALG survey instrument were being piloted and were still to be modified so that they could eventually be used in the rest of the study. The interview was to be carried out as a follow up study to clarify what the students had pointed out in the survey data.

However, in attempt to improve the SALG survey instrument, modifications were made to the instrument after the pilot study. It was noted that in the group of 2015 on which the pilot study was conducted, the SALG survey instrument had 64 question items students were expected to answer. Students suggested the number of items be reduced because the instrument took long to complete. The number of question items were reduced to 34 items in the modifications that followed, thereby reducing the respondent burden. The second aspect to be modified was the inclusion of content related items (see Appendix D, the first thirteen questions). In the original instrument there were no content specific items. This was also done to ensure that questions were relevant to the information sought. Further modifications were made from inputs made by other subject specialists. They advised in the restructuring of the instrument, relevance of response options, and how questions were articulated, as well as grammatical errors, in order to make the instrument comprehensive.

4.3 MICRO STUDY RESULTS OF 2016

4.3.1 Quantitative results from the modified SALG survey of 2016

4.3.1.1 Profile Data of Respondents

This study had 75 participants, a figure much higher than the previous year of 2015. The same also can be said about the number of males in this study which was 46 (61.3%) compared to that of females 29 (38.7%). Table 4.7 shows a summary of the participant profile.

Table 4. 7: Demographic Profile of the Respondents

Variable	Category	Frequency (N)	Percentage (%)
Gender	Female	29	38.7
	Male	46	61.3
	Total	75	100.0
Age	18-19	-	-
	20-21	26	34.7
	22-24	39	52.0
	25 and above	10	13.3
	Total	75	100.0

The greatest number of the respondents were of the age group 22-24 which was 39 (52.0%), while the 20-21 age group was the second with 26 (34.7%) respondents. None was in the age group 18-19, and only a few 10 (13.3%) were 25 years old and above.

4.3.1.2 Reliability Analysis

Reliability analysis was conducted with 34 items on the questionnaire. The Cronbach's Alpha value was very high, $\alpha = .954$. However, the item statics showed two items, 10 and 23, to have values lower than the rest of the other items. These items were excluded from further analysis of the questionnaire data. The researcher also felt further justifiable to remove the two items since during the instructional process these items were not adequately addressed due to time constraints. The removal of the items changed the Cronbach Alpha value to α =.953. The instrument still remained highly reliable with a total of 32 items.

4.3.1.3 Suitability of Data for Factor Analysis

The data was tested for its feasibility for factor analysis by calculating the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett Test. The value of KMO was found to be .867 and the Bartlett's test of Sphericity had a Chi Square value of 1612.050 with significant value 0.000 as shown in Table 4.8.

Table 4. 8: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.867
Bartlett's Test of Sphericity	Approx. Chi-Square	1612.050
	df	496
	Sig.	.000

4.3.1.4 Factor Extraction

From a total of 32 variables analysed, 8 variables had Eigenvalues greater than 1, and a cumulative variance of 73.8%. Table 4.9 shows the 8 variables identified as components in the first column. Thus, according to the Eigenvalue criteria there are 8 major themes or underlying latent factors that can be identified from this data.

Table 4. 9: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	13.27	41.47	41.47	13.27	41.47	41.47	4.824	15.07	15.07
2	2.18	6.80	48.28	2.18	6.80	48.28	3.201	10.00	25.08
3	1.92	6.01	54.29	1.92	6.01	54.29	3.137	9.80	34.88
4	1.65	5.14	59.43	1.65	5.14	59.43	2.812	8.79	43.67
5	1.34	4.19	63.61	1.34	4.19	63.61	2.431	7.60	51.26
6	1.18	3.69	67.30	1.18	3.69	67.30	2.431	7.60	58.86
7	1.09	3.39	70.69	1.09	3.39	70.69	2.414	7.56	66.40
8	1.00	3.13	73.83	1.00	3.13	73.83	2.375	7.42	73.83
Extraction Method: Principal Component Analysis.									

4.3.1.5 The Scree Plot

The Scree Plot Figure 4.2 shows the Eigenvalues plotted against all the 32 variables in the questionnaire. It was used to verify the number of components extracted using the Eigenvalue criteria. The number of components extractable from the data set were the number of plots on the graph above the horizontal line drawn passing through the value of 1 on the Eigenvalue scale. Alternatively, a straight line drawn along the plotted curve starting from the last variable end until the point where the graph starts to curve upwards left 8 points. These points were considered as the number of principal components being sought.

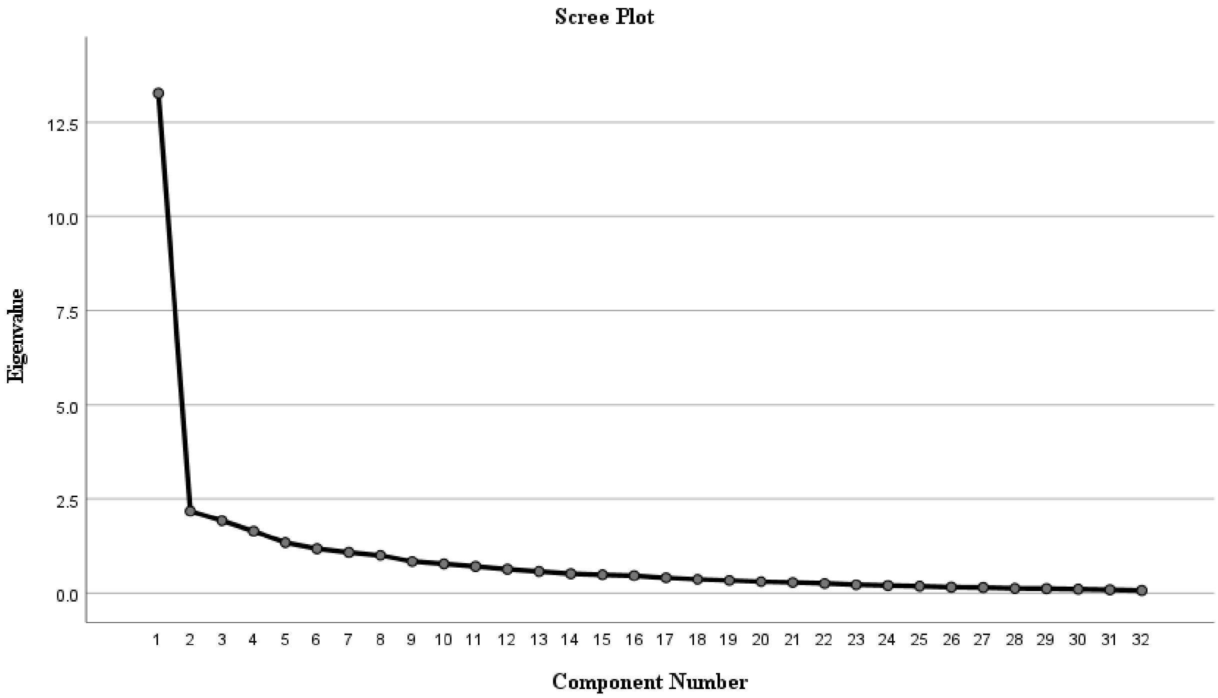


Figure 4. 2: Number of components extractable from the 32 variables

4.3.1.6 Naming the Factors

Factor rotation technique in SPSS was used to identify factors where each variable loaded the most. Table 4.10 shows the factors, their attributes and factor loadings. The factor attributes represent the cluster of variables associated with each factor. Each cluster of variables was used to identify the underlying theme, which then helped to come up with the name assigned to that particular factor. In order to come up with meaningful names, the top one or two loading items which loaded highly onto that specific factor were used. Thus Factor 1 was considered to be associated with building of student self-confidence, hence was named *self-confidence*. Similarly, the other seven factors were named using the same technique.

Table 4. 10: Names of factors (derived from attributes and factor loadings) that influenced learning in participants of 2016

	Factor attributes	Loadings
Factor 1 Building self-confidence to solve complex problems in geometric optics	Feeling at ease when working with complex problems in geometrical optics	.767
	Your confidence to write final examination	.714
	Confidence that you understand geometrical optics	.705
	Your interest to learn more of geometrical optics	.640
	Enthusiasm for the subject of physics	.614
	In the way this module has been taught compared to the way your previous physics module was taught	.598
	The level of difficulty of written tests	.583
	Describing what happens to speed, frequency and wavelength when light goes from one medium to another	.548
	Your willingness to seek help from others when working on academic problems	.443
	The order of priority used to discuss main ideas of the topic.	.414
Promoting strategies that motivate students to solve complex problems in geometric optics: mean = .603		
Factor 2 Participation in class discussions	Listening to discussions during class	.806
	Participating in group work during class	.686
	Participating in discussions during class	.682
Employing strategies that encourage active participation in class discussions: mean = .725		
Factor 3 Knowledge and application of ray tracing techniques with mirror/lens equations	Using the mirror equation and sign convention to determine the position, magnification and size of the image formed by a mirror	.778
	Distinguishing between the roles played by the mirror, lens, and screen in image formation.	.719
	Using the ray tracing method to locate the image position for an object placed a specified distance from a lens	.663
	Using the lens equation and sign convention to determine the position, magnification and size of the image formed by the lens.	.633
	Using the ray tracing method to locate the image position for an object placed a specified distance from a mirror	.625
Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics: mean = .684		
Factor 4 Feedback on graded activities	Presentations by group representatives after discussion of problems in respective groups	.773
	The feedback on my work received after tests	.696
	The feedback received from the instructor on questions posed during class discussions of content	.527
	The level of difficulty of the problems discussed in class	.516
	Laboratory practical activities	.484
	Reading material recommended by the instructor	.419
Providing feedback and guidance on all formative activities and relevant reading materials that meet the required levels of demand of problems discussed in class and in written tests: mean = .569		

Factor 5 Video based learning activities	The quiz written after watching each video presentation	.761
	Video presentations posted on blackboard by the instructor	.679
Encouraging students to watch video materials by compelling them to answer a formative quiz only after watching the video material: mean = .720		

Factor 6 Knowledge and application of the laws of geometric optics	Using Snell's law to predict the path of a light ray as it moves from one medium into another	.810
	Distinguishing between mirror and diffuse reflections	.614
Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics: mean = .712		

Factor 7 Knowledge and understanding of the nature of light	Distinguishing between ray and wave models of light	.808
	Stating and using the key ideas outlined in the ray model of light	.706
Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics: mean = .757		

Factor 8 Knowledge and application of laws of the geometric optics	Describing the operation of optical fibres using total internal reflection	.713
	Applying the ray model, geometrical	.687
Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics: mean = .700		

In summary, the key factors that influenced student learning were those associated with:

1. Promoting strategies that motivate students to solve complex problems in geometric optics.
2. Employing strategies that encourage active participation in class discussions.
3. Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics.
4. Providing feedback and guidance on all formative activities and relevant reading materials that meet the required levels of demand of problems discussed in class and in written tests.
5. Encouraging students to watch video materials by compelling them to answer a formative quiz only after watching the video material.
6. Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics.

7. Identifying and applying knowledge, concepts, skills, and key ideas needed for solving complex problems in geometrical optics.
8. Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics.

This list reduces the findings to only five items (1 to 5) since items 3, 6, 7, and 8 are the same. Thus, according to this list, there are five factors or components that influenced student learning during the implementation of the intervention of 2016. The summary of factors are issues considered in this study to have greatly influenced the learning of geometrical optics concepts by student participants.

4.3.2 Qualitative results from the modified SALG survey of 2016

Students answered the open-ended questions of the SALG survey, positive and negative sentiments were grouped as *strengths of the intervention* and *weaknesses of the intervention*, respectively as listed below.

Strengths of the intervention associated with the instructional approach in general

- Students were more confident and enthusiastic when engaged in collaborative work
- Strategies employed encouraged independent learning leading to better performance in tests and exams.
- Class discussions were well managed because lecturer had good command of subject matter knowledge
- Students were given the opportunity to design laboratory activities on their own
- Students conducted activities under the guidance of the instructor who had high expectations of them
- Strategy enabled difficult content to be understood and to be applied

Strengths of the intervention associated with video materials:

- Videos are helpful because students can recall knowledge by replaying them several times until concept is grasped
- Videos are a better method of delivering content because they promote independent learning
- Videos can be conveniently used at one’s own time
- Reading after watching videos enhances understanding of concepts

- Videos are a better alternative to reading prescribed books and the notes given by instructor.
- Videos are lectures delivered outside the classroom environment and are more helpful than slides

Weaknesses of the intervention associated with the instructional approach in general

- Lecture method is better because the lecturer explains everything
- Students should be guided on how to answer questions at the start of a module rather than waiting for test corrections
- Class discussions should end by summarising key ideas discussed
- Lecturer should accept student answers taken from any other materials used during studies
- The instructor should also post soft copies of study material on blackboard since some students do not have laptops to watch videos
- More laboratory practical work on geometrical optics will help students understand the concepts better
- Students should not be restricted to the use of prescribed textbooks only, but should be allowed to use definitions or explanations from any other textbook of physics
- The lecturer should lecture during class sessions than to expect students to work on their own
- The pace at which content is delivered is slow because the instructor tries to accommodate slow learners

Weaknesses of the intervention associated with assessments

- Quiz and tests seemed to be new ideas because they were more difficult than information given to students
- The instructor should conduct lectures before students can be given a quiz or test to write
- Level of difficulty of problems dealt with in class discussions did not match those on tests because tests were much more difficult
- Questions on quiz and tests were more challenging than information provided on video material

Weaknesses of the intervention associated with feedback

- The instructor should return students' scripts after writing tests when giving feedback, as scripts form part of the feedback process

Weaknesses of the intervention associated with video material

- At times the lecturer distributed videos via class representatives because blackboard was not working, but the method was not efficient
- Video material should be improved to include clear explanations of concepts, summarised notes, and examples of how different types of questions can be answered.
- Enough time should be provided for students to watch videos before class activities or writing a quiz
- Videos not good because they do not provide students the opportunity to ask the instructor questions and to be answered immediately

Weaknesses of the intervention associated with content coverage

- Teaching practice period away from campus rob students of time to adequately cover the content assigned in the course programme
- More time should be allocated to discuss concepts in class and to prepare for and conduct laboratory work

The lists of strengths and weaknesses under different themes are summaries after taking the main idea from several categories. Each participant's response was further examined, and the main idea was taken and represented as a category of its own. These categories were then grouped according to the themes indicated in Table 4.11. Each theme was then counted to determine how many times the theme was mentioned in the participants' responses. The frequency of count representing how often participants talked about a theme was considered to represent how strongly participants felt about that theme. Thus table 4.11 shows a summary of the themes and the frequency of count as a percentage of all counts added together.

Table 4. 11: How strongly participants felt about each educational aspect identified thematically

Code	Themes	Count showing how many times a theme was mentioned	Count expressed as a (%)
1	Content	10	11
2	Assessment	12	13
3	Videos	29	30
4	Feedback	10	11
5	Class discussion	17	18
6	Guidance	3	3
7	Instruction	10	10

8	Learning material other than video material	0	0
9	Lecturer	4	4
10	Post/After class activity	0	0
TOTAL		95	100

Table 4.11 shows how students strongly felt about each of the educational aspects identified as themes in the second column. The strongest sentiments were about the videos (30%), which as pointed out in the previous section, had its positive and negative aspects. The second most influential aspect was class discussions (18%). In the third place was assessment issues (13%). These first three issues shows areas where greater attention was needed, especially with videos and discussions. Content (11%), Feedback (11%) and instruction (10%) were talked about nearly in the same way. Their frequencies are not so small to be ignored. Thus, the issues outstanding indicated in the previous section related to these themes need consideration as well. The least theme to be talked about was the lecturer. It appears few students had something to say about the lecturer.

4.3.3 Interview results from the study of 2016

The interview conducted was a follow-up to the survey administered to the participants, where quantitative data was collected using closed-ended questions. The open-ended questions on the same survey were not answered by every participant. Some participants would leave certain sections unanswered and jump on to answer the following question. So, for purposes of clarifying certain issues, the researcher decided to interview four students in this cohort of 2016, who were purposively chosen according to academic performance of high, middle, and low performers.

Data in this section is provided as key findings in form of conceptualised themes obtained from generated code categories. It is supported by relevant selected quotes from the four student participants interviewed in this study cohort. The questions sought for more information within the same themes identified in section 4.2.2 Table 4.5. The interview protocol that was used consisted of ten questions (see Appendix G). The findings from all the ten questions are summarised and explained as listed in this section:

Content level of difficulty

Content level difficulty was one of the main themes generated through the analysis of the open-ended questions and is reflected in Table: 4.11. The first interview question: *How would you describe the content you learned in this course,* sought to find out more about how participants felt in terms of complexity of the content, whether they perceived it as hard or simple to deal with. Six subthemes: *broad content, limited time, large class size, poor resources, content moderate and intellectually challenging tasks,* characterizing the nature of the content were generated from the analysis of the interview scripts. In terms of the level of difficultness, the content was perceived as broad but neither difficult nor easy, though involving intellectually challenging tasks. The limited time and lack of resources affected content coverage.

> *"It was very broad as geometrical optics is, but we, we typically did not study the whole of it because of time factors, and I think resources. But then generally the topic as a whole is very interesting. And I think if you can go in more detail with it, I think it's, it's, it's very interesting. But then the problem was that as large as we were as a group, and the fact that we were large as a group was the main disadvantage, because even the lecturer was trying his best to accommodate all of us. He could not because when he was dealing with one group, and then the other group had a problem, he could not finish within the time frame. So, it was basically the main problem because the chapter is, is it's huge. So, I think it needs more time for it to be covered. But basically, it's a very interesting chapter that we did, and yeah."* ($P1_{2016}$).

Ability to solve physics challenging problems

The impact of the instructional approach on students' reasoning ability was sought through the second question: *How did the instructional approach influence your ability to solve challenging problems in physics?* Participants' responses identified: *video benefits, videos demonstrations, peer consultations* and *making sense of the physics context before attempting the question,* as factors that played an important role in improving ability to solve physics challenging problems.

> "*The instructional approach, because it was having the videos, and I had them in my laptop, it was easy for me to go back there, wherever I don't understand. I can go back and re-listen, so that I can capture whatever that is supposed to be learnt. In a way, these videos, I can say they helped me a lot. Because at the end of the videos, I had everything that I wanted to understand, being understood, because I went back, or say, I went back to revise the videos more times again, unlike compared to a lecture in class, to say, it's a once off lecture and then everything just ends there, but with the videos, they helped me a lot, and they helped me to solve the challenging problems in physics".* ($P3_{2016}$)

The aforementioned statement shows some of the learning aspects students benefited from the use of videos which were helpful in developing their ability to solve physics problems. Participants had to also make sense of the context of a problem before attempting it:

> "*Okay. Right, because in the last module of physics, because we used to, with our lecturer, we used to design strategies, we use to pick out the important facts from the question step by step, show diagrams to say, okay, if this is the case, we draw the lines, we show the rays, we show whatever that is given on the question,* then *from there, we move to the question, after taking out whatever given data is there, we now come to make sense of it. Now, with that experience, I can say I've learned a lot. It's not a matter of just reading the questions, but do you have to first understand and make sense of it, you have to pick out the important facts, draw diagrams wherever is necessary, so that you make the question easier for you to understand before you can come to answer whatever question that is asked to you. So, in conclusion to that, I can say 70%, I think, I am ready for any question in physics, with regard to the approach that we learnt, on approaching questions. Yeah, I think so".* ($P3_{2016}$)

The hybrid nature of the course

The course was delivered using both face-to face and online-video approach experience (synchronous and asynchronous). Participants were asked what they thought about mode of course delivery: Question 3: *How would you describe the way the course was delivered in general?*

> *"Yeah, according to me it promotes the understanding of concepts. What I can say is that with lecture method, you just go and listen to the lecturer, even if there is interaction, the interaction is not much effective than the interaction that takes place when you have already watched the videos and tackling questions."* ($P2_{2016}$)

This response was from one of the participants. The response reflects an acknowledgement of the positive impact the instructional approach had on student participants. It compares the hybrid delivery nature of the course with that of the traditional non-interactive lecture method, and considers the new approach as promoting conceptual understanding. Analysis of all responses with regard to the hybrid delivery nature of the course generated three sub-themes: *created enabling learning environment*, *technology promoted learning interest*, and *exposure to design-based laboratory experimental investigations*. These are characteristics or factors that tend to promote conceptual understanding in the process of teaching and learning.

Out of class assistance

Post class activities are undertaken to ensure consolidation of what transpired in during class time. It becomes necessary that students remain engaged in learning activities that support the learning that has already taken place for the student to remain competent. Information on how students engaged themselves with the content post class activities was sought through the following question: Question 4: *Was there any assistance or extra help you could get after class regarding some things you may not have understood during the in-class session? Please explain.*

> "*Yes. After the lesson times, I used to have chat with my classmates to say, but I didn't understand the following, then I highlight, I tell them this to me does not make sense, then we talk about them. Then from there some of the things I cannot say I was happy after chatting with my classmates. But then at least they gave me that idea to say okay, if you can check the following the following can be right. Then from there, I go and consult my reading materials with a University Physics [textbook], then I check in there for content to say okay, if they said I should check the following, for instance, to help me, but then, so far, I cannot say everything that we did in class was really helpful. Like helpful in everything I can say. But then it, it forced me to go and read at least but not much. I can say not much, but a bit I had to read for myself so that I can understand. And also, of course, I used to come to my instructor say the lecturer for some help where I don't understand and ask the question. So, to say, please sir, explain what this means, or how do I interpret this one?"* ($P3_{2016}$)

The quote shows three main factors that may be used to characterise participants' activity post class events: *consultations with peers*, *consultations with the lecturer* and *independent learning*. These factors were common in all responses of the four participants. Thus the three were considered to be sub-themes characterising the nature of out of class assistance as experienced by participants.

Class discussions

Face-to-face or class meetings is the phase where detailed engagement with content is expected to take place in terms of FCA. Various forms of interactive engagements may take place depending on objectives of the lesson. The four participants were asked on how they perceived the classroom discussions that took place: Question 5: *How would you describe the classroom interactions during the face-to-face sessions?* The most important sub-themes that emerged were the following:

use of peer teaching strategies, exposure of misconceptions, interest and motivation, problem solving strategies, fear of being judged by classmates, unpreparedness for class discussions, time consuming discussions. Three of these themes can be identified in the extract quote provided below.

> *"I think the student to student interaction was very helpful in my case, because as we were seated, if my group was not able to let's say, we're solving a certain problem as the class, if my group was unable to understand the question, or we were unable to solve the question, then we move to the next group and ask them . . . I would prefer for the instructor to randomly ask a student if they can explain something because sometimes as students, we tend to fear to raise up our hands even though we have an idea of what we are being asked of the question or the problem . . . let's say there's a question and then the instructor or ask someone to say something, even though that the student might not say the right thing, they might say the wrong thing. And then that's when we will be able to spot out the misinterpretation of, to say okay, this person is having a problem here, here, here and here. And then we're able to define and identify the misconception . . ."* ($P1_{2016}$)

The seven sub-themes show both positive and negative mixed feelings about how the discussions proceeded. The first four themes listed above show interactive strategies enhancing understanding of the content, while the last three themes show issues that may work against the instructor's intentions, and need to be addressed as they arise when conducting face-to-face discussions.

Teaching/Learning materials

Instructional materials play a very important part in the teaching-learning process, for they play the role of teaching-learning aids aimed at achieving the planned learning outcomes. Participant views were sought out on this aspect of the teaching-learning process: Question 6: *How would you describe the teaching-learning materials used during the course of the semester for this module?* Two main issues common to, and raised by all four participants were *advantages and weaknesses of videos* as instructional material.

> *"Yes, I can say yes, I was able to understand what he was saying. Because it was not a once off watch, you would watch and re-watch and re-watch and re- watch again, until you clearly understand whatever that you were expected to understand . . .*
>
> *. . . But they were very helpful because you can go back. If you don't understand, take a break go out. Take a deep breath, come back, and watch again. And make sure you are clear on before you go on, unlike a lecture like lecturing in classrooms, which is a once off*

> *lecturing, which you cannot rewind and re-watch again. Yeah, there were very helpful"* (P3 2016).

The quote from one of the participants given above shows an example of some of the advantages cited by most participants. Likewise, the quote below from one of the students also cites an example of weaknesses associated with the videos.

> *"The material, I can say was relevant to our study, but in the material that we were given, there were no references, the references that we can use to go out, to say this is the book that was recommended. If you feel the video itself was insufficient, you can go and refer to this book . . .*
>
> *. . . We were not given more time to analyse the videos and understand whatever the videos are analysing. So, we were not given enough time to prepare. Because we can be given the videos today around four, and also be requested at the same time to understand whatever is in the video and be also be able to write a quiz the following day, so we were given a few hours to analyse the video and write the quiz after that and discuss the content is giving . . .*
>
> *. . . Let me just say the videos that were given to us by our instructor they were giving us full information about the concept, then thereafter they will give us the diagram, the diagram that is in line with the concept. But not the practical demonstration. I mean not the practical picture of the concept . . ."* (P4 2016).

Examination preparation

Examination preparation is a process that takes place during the course of the semester. Various activities are prepared and given to students in preparation for this summative assessment. Thus by the time students are assessed, they are either prepared or not. Views on participants' preparedness were sought in the following question: Question 7: *How prepared were you for the end of semester examination after going through the module?* Two main issues came up when the information was processed: *expression of positive feelings of preparedness* and *inefficiencies of Black board Learning Management System.*

> *"If I have to rate myself personally, I would say on a scale out of 10, I was prepared, six out of 10, because I think the time frame, the time factor is the one that is always costing us, as well as the resources that we were using to share the videos and other materials*

because you find that, if, let's say you we preparing and then the lecturer said that there is a video, there is an uploaded video on Blackboard, you have to, like most of the time you struggled with Blackboard having to access the videos. So, you find that it even demotivates, demotivated us because if you can't find the material most of the time, you're like, I'll get it some other time. So that delays you from studying. Because you always say I get it some other time. And then when you wait for the other time to come, that's when you are wasting your time. So yes, they helped us to study to prepare ourselves, but were not, personally I was not well prepared for the exam", ($P1_{2016}$).

The sentiment revealed in the quote shows participants were not fully prepared for the examinations because of the inefficiencies of the blackboard learning management system (BLMS). An interesting observation though, from the participant statement is that, taking into consideration that examinations were written at the end of the semester after the instructional process had ended, the BLMS reason provided seem not a sufficient reason to justify participants' unpreparedness for writing the final examination, unless participants managed to get the videos during the examination time. This reveals that participants did not understand the purpose or role of the videos in the whole process of FCA.

Limitations of the instructional approach

Every instructional approach has its strengths and weaknesses. The interview revealed six sub-themes that could be regarded as factors contributing to the inefficiencies of FCA: *additional programme demands, time constraints, inefficiencies of the BLMS, lack of smart gadgets for video watching, misunderstanding the role of videos,* and *inconsistent quiz assessment tasks demands*. Participants were of the view that the instructional approach failed to take into consideration that not all students had smart gadgets such as computers, smart cellphones or tablets.

"Some of us we don't have laptops to go and watch the videos in our own spaces. If you don't have a laptop, you have to go through the lab, the labs in this university. So and we know how this university is, the material is not available . . .

. . . Since it was posted on Blackboard, some of the students couldn't reach it on their own time whenever they wanted it. They would have to go and ask for laptops and materials for them to watch it . . .

. . . But we know, these labs, they are not only for third year students in this DMSTE, but they are also for the whole university, <u>so you will have to queue for the computer</u>", ($P2_{2016}$)

In addition to lack of smart gadgets, the BLMS was not efficient, where videos uploaded by the lecturer for students' to access could not be accessed on time to make meaningful preparations for their face-to-face meetings. These limitations and those not highlighted in the quote but indicated earlier on characterised the weaknesses of the instructional approach.

Sequencing of study units

A logical sequence of sub-topics of content under study is an important part of instructional delivery. Student participants' were asked for their opinion about this: Question 9: *How would you describe the way the main ideas in the topic of geometrical optics were sequenced?* Participants' views concurred with the particular order of arrangement of the study units.

". . . because if one can be taught ray model that person is going to be able to understand reflection of light, refraction of light, total internal reflection" ($P4_{2016}$).

"The sequence or the way the content was organised was very well organised. Because before you can talk about reflections, in a concept of reflection we use rays to analyse this concept, and also in the concept of refraction we use ray models to analyse these" ($P3_{2016}$).

The quotes show that participants are of the view that *ray model simplifies further studies on behaviour of light*, and in terms of how the units were arranged, these were *logically sequenced study units*.

Laboratory experience

Laboratory experimental investigations help to consolidate theory discussed in class. Information seeking how participants felt about laboratory experience after going through the course was obtained through the question: Question 10: *How would you describe your experience with laboratory activities*? Two themes were generated from the analysis of the data: (1) *theory most helpful in designing of, and performing lab experiments,* and (2) *lack of pre-lab discussions on design activity and practical experiment.* These themes serve to describe participants laboratory experience, hence are considered sub-themes of *laboratory experience*, which is the main theme under discussion in this section. The first interview quote from one of the participants ($P2_{2016}$)

substantiates that theory studied in class was helpful to participants at the time of carrying out experimental investigations in the laboratory.

> *"You can reflect back to the theory, what we have learnt in class. It's actually what we're going to do in the lab. We're just doing the practical part of it. The theory we knew it. So when going to the practical, to the lab, we knew what we were going to do"* ($P2_{2016}$).

The second quote, also from another participant, provides supporting evidence on the view that, though students had theory that helped them to perform laboratory investigations prior to the actual laboratory experience, they had to design the experiment first, but this design phase had a weakness in that it was never discussed with the instructor. No brief session as well was held with the instructor, to discuss the actual process of conducting the experiment prior the laboratory session.

> *"I have to say no, here, because before going to the practical session, we never really had the time to talk about the practical part of the topic as a whole . . . we never really had the time to sit down and say okay, we are going to talk about the theoretical part of the practical, we only went through the topics, theoretically as they are, but we never really talked about them having to apply them in the labs. So, and I think that our problem here, it was that we didn't have the time to talk about the theoretical part of applying the theory part to the practical part . . . And then another factor was time as well. We were given a very limited time to do the design and go to the lab and to the practical and come back to conduct a report. So, the time that we had there was very limited"* ($P1_{2016}$).

A reason to justify the failure to conduct prior discussions was seen as due to shortage of time.

Changes to the intervention

Overall changes were made to the intervention, based on the negative sentiments raised by the student participants in responses to both open-ended and interview questions. Such changes included: a brief lecture of about fifteen minutes at the beginning of the class, summarising key ideas of the topic – this was done to accommodate students who preferred lecture sessions than the FCA. A brief analysis of how questions were to be answered during the discussion sessions was given-this was done to accommodate students who felt that guidance on how to answer questions should be provided at the start of a module than to wait for feedback for tests. A summary of key ideas studied during each session was provided at the end of each session as per sentiments raised. Improvements on delivery of video material were made and involved an agreement with the class for students to share the material with each other, especially when blackboard system was not operating efficiently. The instructor allowed students to collect the material at his office at designated times. In addition to video material, additional notes were also provided to students. When tests were written, students were not given their scripts and some of the students were not happy about it, labelling it ‘lack of feedback’ on the part of lecturer. To improve on this issue, students were permitted to see their scripts but requested to hand them back, since the lecturer used them as part of teaching material when guiding students on how they should correctly answer the questions given to them. It was an agreement by the whole class to take such an action. These were improvements made to the intervention for the next iteration.

4.4 MICRO STUDY RESULTS OF 2017

4.4.1 Quantitative results from the modified SALG survey of 2017

4.4.1.1 Profile Data of Respondents

In this study, the number of participants (123) was higher than in each of the two previous groups of 2015 and 2016. The same trend of a greater number in males 89 (72.4%) as compared to their female counterparts 34 (27.6%) is also exhibited here, as can be seen in Table 4.12.

Table 4. 12: Demographic Profile of the Respondents

Variable	Category	Frequency (N)	Percentage (%)
Gender	Female	34	27.6
	Male	89	72.4
	Total	123	100.0
Age	18-19	2	1.6
	20-21	39	31.7
	22-24	59	48.0
	25 and above	23	18.7
	Total	123	100.0

The majority of the respondents 59 (48.0%) were of the age group 22-24. This was followed by the 20-21 age group with 39 (31.7%) of the respondents. A reasonable number 23 (18.7%) of the participants were 25 years and above, while only 2 (1.6%) participants were of the age in the range of 18-19.

4.4.1.2 Reliability Analysis

The total number of items analysed were 34. Cronbach's Alpha came out with α = .939. Further inspection of the item-total statistics showed one item with a mean value of 2.93 while the majority had mean values above 3.25 to 4.44. The researcher thought it was best to remove it based on the fact that it was also not adequately treated during the instructional process. The Reliability coefficient became .940 after its exclusion from the list of items analysed. Further analysis was then conducted with 33 items.

4.4.1.3 Suitability of Data for Factor Analysis

The data was tested for its feasibility for factor analysis by calculating the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett Test. The value of KMO was found to be .887 and the Bartlett's test of Sphericity had a Chi Square value of 2082.098 with significant value 0.000 as shown in Table 4.13.

Table 4. 13: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.887
Bartlett's Test of Sphericity	Approx. Chi-Square	2082.098
	df	528
	Sig.	.000

4.4.1.4 Factor Extraction

From a total of 33 variables analysed, 8 variables had Eigenvalues greater than 1, and a cumulative variance of 65.7%. Table 4.14 shows 8 extracted factors in the first column. Thus, according to the Eigenvalue criteria there are 8 major themes or underlying latent factors that can be identified from this data.

Table 4. 14: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.72	35.52	35.52	11.72	35.52	35.52	4.37	13.23	13.23
2	2.26	6.84	42.35	2.26	6.84	42.35	3.23	9.78	23.00
3	1.72	5.21	47.56	1.72	5.21	47.56	3.20	9.71	32.71
4	1.41	4.27	51.83	1.41	4.27	51.83	3.15	9.55	42.26
5	1.21	3.67	55.51	1.21	3.67	55.51	2.81	8.52	50.78
6	1.21	3.65	59.16	1.21	3.65	59.16	1.90	5.75	56.53
7	1.13	3.41	62.57	1.13	3.41	62.57	1.60	4.83	61.36
8	1.04	3.14	65.71	1.04	3.14	65.71	1.43	4.35	65.71

Extraction Method: Principal Component Analysis.

4.4.1.5 The Scree Plot

The Scree Plot Figure 4.3 shows the Eigenvalues plotted against all the 33 variables in the questionnaire. It was used to verify the number of components extracted using the Eigenvalue criteria. The number of components extractable from the data set were the number of plots on the graph above the horizontal line drawn passing through the value of 1 on the Eigenvalue scale. Alternatively, a straight line drawn along the plotted curve starting from the last variable end until the point where the graph starts to curve upwards left 8 points. These points were considered as the number of principal components being sought.

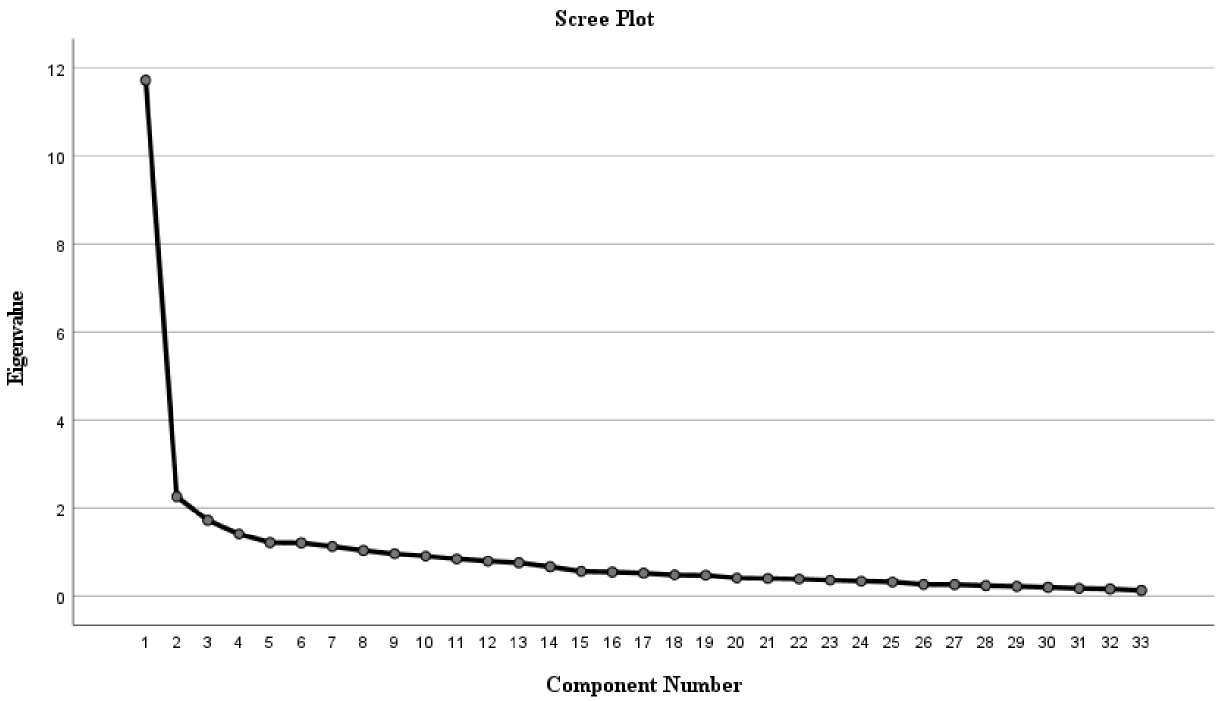


Figure 4. 3: Number of components extractable from the 33 variables

4.4.1.6 Naming the Factors

Factor rotation technique in SPSS was used to identify factors where the variables loaded most. Table 4.15 shows eight factors and their corresponding cluster of variables, and their factor loadings as well. The cluster of variables for each factor are under the heading titled factor attributes and were used to identify the underlying theme associated with the factor. In order to come up with meaningful names for the factors, the top one or two loading items on each factor were used. In Table 4.15 the three topmost loading items were used to identify the underlying theme for that set of variables. Thus Factor 1 was associated with building the self-confidence of students, hence was named *self-confidence*. Similarly, the other seven factors were named using the same technique.

Table 4. 15: Names of factors (derived from attributes and factor loadings) that influenced learning in participants of 2017

Factors	**Factor Attributes**	**Loadings**
Factor 1 Building interest and self-confidence for solving complex problems.	Enthusiasm for the subject of physics	.719
	Feeling at ease when working with complex problems in geometrical optics	.696
	Confidence that you understand geometrical optics	.609
	Your confidence to write the final examination	.591
	In the way this module has been taught compared to the way your previous physics module was taught	.590
	Your interest to learn more of geometrical optics	.564
Developing students' interest and confidence for solving complex problems: mean = .628		

Factor 2 Participation in class discussions	Participating in group work during class	.671
	Listening to discussions during class	.648
	Presentations by group representatives after discussion of problems in respective groups	.550
	The level of difficulty of the problems discussed in class	.540
	Participating in discussions during class	.526
Employing strategies that encourage active participation in class discussions when solving complex problems in geometrical optics: mean = .587		

Factor 3 Design and implementation of investigation activities	Laboratory practical activities	.739
	Pre-laboratory design activities	.714
	The order of priority used to discuss main ideas of the topic	.508
	Distinguishing between ray and wave models of light	.478
	Stating and using the key ideas outlined in the ray model of light	.476
	Reading material recommended by the instructor	.434
Developing key geometrical optics ideas in students through reading of recommended materials and conducting practical investigations: mean = .558		

Factor 4 Knowledge and application of ray tracing techniques with mirror/lens equations	Using the ray tracing method to locate the image position for an object placed a specified distance from a mirror	.766
	Using the ray tracing method to locate the image position for an object placed a specified distance from a lens	.674
	Distinguishing between the roles played by the mirror, lens, and screen in image formation	.670
	Using the mirror equation and sign convention to determine the position, magnification and size of the image formed by a mirror	.591
	Using the lens equation and sign convention to determine the position, magnification and size of the image formed by a lens	.549

Developing student abilities for solving complex problems in geometrical optics through the use of the sign convention and ray tracing techniques: mean = .650		

Factor 5 Knowledge and application of geometric optics laws	Using Snell's law to predict the path of a light ray as it moves from one medium into another	.719
	Describing what happens to speed, frequency and wavelength when light goes from one medium into another	.602
	Distinguishing between mirror and diffuse reflections	.584
	Describing the operation of optical fibres using total internal reflection	.513
	Applying the ray model, geometrical optics laws and principles in solving problems	.472
Developing and applying knowledge of concepts, laws, and principles of geometrical optics for solving complex problems in geometrical optics: mean = .578		

Factor 6 Feedback for guiding instruction	The feedback received from the instructor on questions posed during class discussions of content	.773
	The feedback on my work received after tests	.571
Providing feedback to all formative graded and non-graded activities associated with class discussions: mean = .672		

Factor 7 Video based learning activities	Video presentations posted on blackboard by the instructor	.731
	The quiz written after watching each video presentation	.509
Encouraging students to watch video materials by compelling them to answer a formative quiz after watching the video material: mean = .620		

Factor 8 Collaborative work	Your willingness to seek help from others when working on academic problems	.815
Encouraging collective effort when students are working on academic problems: mean = .815		

In summary, the key factors that influenced student learning were those associated with:

1. Developing students' interest and confidence for solving complex problems.
2. Employing strategies that encourage active participation in class discussions when solving complex problems in geometrical optics.
3. Developing key geometrical optics ideas in students through reading of recommended materials and conducting practical investigations.
4. Developing student abilities for solving complex problems in geometrical optics through the use of the sign convention and ray tracing techniques.
5. Developing and applying knowledge of concepts, laws, and principles of geometrical optics for solving complex problems in geometrical optics.
6. Providing feedback to all formative graded and non-graded activities associated with class discussions.

7. Encouraging students to watch video materials by compelling them to answer a formative quiz after watching the video material.
8. Encouraging collective effort when students are working on academic problems.

4.4.2 Qualitative results from the modified SALG survey of 2017

The responses from student participants were analysed to identify the strengths and the weaknesses of the intervention.

Strengths of the intervention associated with understanding of the content

- Content was well outlined and clearly presented to everyone such that it was understandable.

However, there were a number of issues raised by some participants which could be regarded as negative sentiments, which the participants felt needed to be addressed if the intervention was to be improved. These negative sentiments related to understanding of the content are listed as weaknesses of the intervention in terms of understanding the content.

Weaknesses of the intervention associated with understanding of the content

- There were concepts that were not fully covered during the implementation of the intervention and as such participants felt this had an effect on mastering the content. Such content included: Fermat's principle, refraction of light, proving some of the laws of geometrical optics, confusion on how the ray model using the approach of diffraction of wave and how it is treated in textbooks using water waves, the sign convention, and ray tracing diagrams.
- There was a need to conduct more experiments or laboratory investigations as a way to strengthen the theory studied in class. Since students were required to design an investigation as part of the course requirements, they felt not enough guidance was given on how to design the investigations and how to write the laboratory report after conducting the experiment. Alternatively, more practical demonstrations could be performed during class time by the instructor so that they could see how the theory was really linked to real-life situations. Others felt tests and examinations should include some aspects of practical work so that students do not see the two as separate things, but one complementing the other.

- There were concerns about content delivered to be too difficult for students due inadequate matric background. Thus, they felt the instructional process did not factor in their disadvantages.
- There were issues raised about the need to revisit the content placed on videos in class, together with the instructor giving explanations, since not all the content posted on videos was understood by the students.
- There were concerns that the content was too much such that it needed additional class time, even it meant weekends as well.

Strength of the intervention associated with assessment issues

The following are positive sentiments from students regarding assessment:

- Questions or problems addressed during class time were at par with those answered during tests and the quiz.
- The quiz was very helpful in that students could prepare for the in-class discussions
- Writing a lot of assessments helped them develop a greater passion for the subject

Weaknesses of the intervention associated with assessment issues

Negative sentiments expressed by students in their responses were:

- The instructor was not making use of continuous assessment to monitor students' progress
- The level of difficulty of problems or questions used in assessments was lower and should increase
- The quiz assessment should not always be multiple choice but should include free response questions
- Not enough time was being given students to prepare for quiz and tests
- Though assessment was necessary it should not always take place
- The level of difficulty of questions or problems was very high. To balance this difficult challenge, it was better to alternate one difficult test with another simple test, or to mix less challenging with more challenging questions. The nature of the questions or problems were also difficult to understand because of the physics language, which was too technical, hence made the problem situation difficult for them to understand. If the language was understandable, they could easily solve the problems. This language problem also made the questions or problems tricky to answer.

- Compared to problems solved during class discussions, the level of demand of the questions or problems in tests was higher compared to those solved during class discussions
- It was not advisable to give students a lot of work two weeks before the semester-course ends

Strengths of the intervention associated with feedback

- Not much was said about positive sentiments, except that the lecturer was neither fast nor slow but moved at the same pace as his students, and that students were provided with feedback after every written quiz or test.

Weaknesses of the intervention associated with feedback

As far as feedback was concern the following negative sentiments were raised:

- The instructional process lacked integration of feedback
- Provide student scripts in order for them to see where they went wrong
- Instructor should give back student scripts after they had written a test. This opinion originated from the fact that the instructor wanted to study how students responded to various questions in formative tests given. He therefore asked the students to allow him to retain the scripts after they had written a test and was marked. However, the participants were allowed to view their scripts at any time they wanted but not to collect them and go away. So, this was interpreted as lack of feedback from the instructor, even though after each test the questions or problems were revised and discussed how students were expected to respond.
- Provide feedback for to all formative activities such as group presentations and group discussions conducted in class

Strengths of the intervention associated with videos

Positive sentiments associated with videos were:

- Videos have an advantage over other study materials in that they can be repeatedly played, watched, and listened to, anywhere any time, when explanations are not well understood.
- Watching and listening take less time than reading books, hence videos are time saving.
- That videos should be used in all future lessons instead of attending classroom lectures
- Videos created by instructor were preferred compared to those downloaded from websites.

- Videos are considered by students as more helpful because they were more appealing to students compared to reading books.
- Videos were used more as source of their information compared to reading books
- Students recommend each other to use videos for their studies because they accommodate different learning styles
- Students preferred the instructor to put more videos online because they believed videos improved their performance.
- Each and every student is forced to watch the video and bring the knowledge that he /she saw in the video into the class for discussion

Weaknesses of the intervention associated with videos

Participants' perspectives were that:

- Videos lacked examples to demonstrated how to respond to complex questions, and in general they were not accompanied by questions for self-assessment
- After writing a quiz, let the student and lecturer discuss the concepts presented in the video before treating what is not in the video.
- The videos should be short and focused on a specific concept in a topic
- Students should record themselves when making group presentations of which the videos would be distributed to others.
- The instructor should not rely on video downloaded from the internet but should create his own since he would be able to put the right information, he would like the students to have.

Strengths of the intervention associated with class discussions

Participants pointed out the following issues:

- Group discussions had the advantage that difficult problems could be solved by students sharing ideas, thus minimising possibilities of having individual students getting stuck.

Weaknesses of the intervention associated with class discussions

The following issues were pointed out by participants:

- Where students were making presentations in class, be they at group level or individually, the students should support their arguments with scholarly reasons, and the instructor should provide final comments.
- Students should work on as many problems as possible during class time
- Before in-class activities commence, the instructor should summarise key ideas contained in the videos watched.

- During class discussions, the instructor should constantly touch on aspects presented in the videos watched in order to give clarity to concepts studied through independent learning.
- Provide an opportunity to discuss exam related questions
- Let students work in pairs for every activity unless it is laboratory practical where five people may be accommodated

Weaknesses of the intervention associated with guiding students

There were no strengths or positive sentiments given by participants except the following summary of negative sentiments or disadvantages:

- Instructor should provide guidance on how the concepts link with each other after and before completing the course outline
- Provide semester calendar showing when students would write quizzes, and tests to minimise pressure
- Carefully listen to the learners' queries and try to clarify them in a way they can be satisfied
- There is need to provide guidelines on how to design an investigation/experiment, and to assist in conducting the actual investigation/experiment because students commit errors or take wrong readings during the procedure, which affects the final results of the investigation/experiment.

Strengths of the intervention associated with Instruction

Summary of participants' positive opinions about the instructional approach in general:

- The strategy helped students to learn better because students were guided to focus on specific aspects of the content, thereby allowing them to cover the content within a short space of time, revision was always ready as one could replay the video lectures.
- Students were satisfied with how the content was delivered in comparison to the way physics was taught in other years because the new approach forces students to think critically, leading to understand the topic.
- The strategy helped to raise students' curiosity in learning Physics and build confidence in themselves that they can do well in Physics
- The lectures were excellent because any part of the content could easily be revisited if not properly understood.

- The strategy should be used in other semesters because its enjoyable while gaining knowledge.
- The strategy benefited most students even with better grades because it accommodates different learning styles.
- The face-to-face contact sessions are interesting because they use very powerful strategies of teaching and learning.

No weaknesses were highlighted about the instructional approach as such.

Strengths of the intervention associated with learning materials other than videos

Not much was said under this aspect of learning except the following:

- Instructor provided additional reading material that helped a lot during in and out of class activities

Weaknesses of the intervention associated with learning materials other than videos

Summary of negative sentiments from participants:

- More materials should be provided with examples of how to solve problems using appropriate principles
- There should be slides or at least a prescribed book for which students should read and study other concepts other than videos
- Study guides materials should also be uploaded on black board

Strengths of the intervention associated with the lecturer

- The lecturer promoted learning rather than students competing against each other, presented lessons with passion.
- Lecturer encouraged reasoning and was interested in students understanding the concepts being taught.
- Even though students found the work demanding, the lecturer tried his best to meet students halfway by explaining misconceptions whenever necessary, in and out of class, asking where we didn’t understand.

No weaknesses of the intervention associated directly with the lecturer were provided.

Strengths of the intervention associated with post class activities

Not much was said in positive sentiments about this issue other than the following:

- Students appreciated a lot of work given to them for post class practice, of which some of the work required students to go an extra mile to find information

Weaknesses of the intervention associated with post class activities

A summary of negative perceptions some participants provided are listed below:

- Lot of work given for practice make students loose concentration because the workload subjects students to lot of pressure
- Students are given a lot of work but there is no time cover all of it
- Give students more activities to work on which require them to reason during teaching practice period
- Promote individual work than group work when students are not in class

The lists of strengths and weaknesses under different themes are summaries after taking the main idea from several categories. Each participant's response was further examined, and the main idea was taken and represented as a category of its own. These categories were then grouped according to the themes indicated in Table 4.16 below. Each theme was then counted to determine how many times a theme was mentioned in the participants' responses. The frequency of count representing how often participants talked about a theme was considered to represent how strongly participants felt about that theme. Thus table 4.16 shows a summary of the themes and the frequency of count as a percentage of all counts of all themes.

Table 4. 16: How strongly participants felt about each educational aspect identified thematically

Code	Theme	Count showing how many times a theme was mentioned	Count expressed as a (%)
1	Content	19	11
2	Assessment	21	12
3	Videos	39	22
4	Feedback	14	8
5	Class discussions	9	5
8	Guidance	5	3
9	Instruction	35	20
10	Learning material other than videos	5	3
11	Lecturer	19	11

12	Post class activity	9	5
TOTAL		175	100

Examination of Table 4.16 above shows that the greatest influence in learning came from video material (22%). Participants also felt strongly about the instructional approach (20%) in general, though slightly less than what they did for the video material. Issues about the content, assessment, and the lecturer were talked about nearly in the same way (11%, 12% and 11% respectively). The rest of the other issues represented by the other themes were talked about but not that much, with guidance (3%) and leaning materials other than videos (3%) at the bottom of the list.

4.4.3 Interview results of the study of 2017

There were four students selected for the interview. They were selected according to how they were performing academically as high, middle, and low achievers. There were ten questions on the interview protocol, and all findings from these questions are presented in this sections. The questions were asked as a follow up to what students responded in the SALG survey open-ended questions, to get a deeper insight about what student participants thought of certain issues that influenced their learning during the implementation of the intervention. From each question, the core idea was deduced and became the main theme to be investigated in the interview. Thus the findings from each question have been summarised through grouping of categories after coding, forming sub-themes used to characterise the main themes as listed and described below.

Content level difficulty

Content studied by a student forms part of a course design. Its level of complexity is a factor that determines students' performance as well. As such, students' views were sought through the question: Question 1: *How would you describe the content you learned in this course?* The interview revealed (1) *mixed feelings on the nature of content*, and highlighted (2) *advantages and disadvantages of videos*. The first participant thought the content was broad and complex. The second thought the content was difficult because he could not relate it to real-life situations, in addition to tests that were challenging. For the third participant, it was not difficult, and neither difficult nor simple for the fourth participant.

> *"OK. I see that it differs with certain aspects, like where we are, because geometric optics is broad. You find that at some point the level is there and the other one is abstract . . . but then I will say that [in] overall it was complex"* P5$_{2017}$).

"OK, I thought at the beginning the content was not very difficult, but was very easy, but as time goes by, I realized that I can't relate some of the things I learned in the content in real life situations . . . That's why I can say this content was very difficult in a way, and then also, it was challenging. I could read and think that I understand but then when test comes I can see I'm not ready for the test" $P6_{2017}$).

"This contend, I've learned it before at secondary school in my grade 11 level. So it was not that difficult because it was a sort of revision of what I did" $P7_{2017}$).

"OK, according to me geometrical optics is, I can say, its average, because, I can't say its average but close to simple because some topic areas, we have already done it in previous grades. So we were now moving little bit deeper in that content, like those ones of refractions" $P4_{2017}$).

As can be observed in the quotes above, the mixed feelings are about the nature of the content. Only one participant talked about advantages and disadvantages of videos.

". . . <u>It was complex because you have to watch the videos being alone at some point, you have to watch them being alone</u> . . . there is no one to explain except the one who is doing the video so then <u>there is no way that you can ask the person questions</u> . . . with the video, if you don't learn, if you don't understand <u>you can go back, review watch again</u>, so it was challenging but as you continue it becomes much simpler to grasp" ($P5_{2017}$).

The underlined segments show where the disadvantages and advantages lie in this quote, reflecting the participant had mixed feelings as well on videos.

Ability to solve physics challenging problems

The interview revealed three learning aspects through the question: Question 2: *How did the instructional approach influence your ability to solve challenging problems in physics?* These aspects were: (1) *gained some skills for solving challenging problems*, (2) *strengths and weaknesses of videos*, and (3) *critical thinking instructional strategies*. The following quote from one of the four participants shows an example of sub-theme (1).

"OK, I think it is very simple, the skill is just <u>you have to be analytic</u> by yourself. You have to be able to analyze and be able <u>to listen carefully</u>. So <u>you must have a listening skill</u>, and then <u>you have to analyze the content by yourself</u>, and then <u>you have to be able to describe</u> what the person who is in the video is explaining there. So you have to be

analytical and you have to be a good listener also. So <u>those are the other skills that I think I have acquired</u>" (P5$_{2017}$).

The participant identifies ability to analyse, listening skill, and ability to describe, as skills that helped develop the ability to solve physics challenging problems. The strengths of the videos can be also seen in further elaboration given by the participant.

> *". . . I learn best when using videos . . . So after I watched the video for several times, then it becomes much easier for me to participate during the classroom presentations or discussions in the classroom. . . It allows me to [participate] because during the time of watching the video, you grab things by your own, you start to understand and analyse the content by your own before you can go to class. Therefore it makes things easier when you're in class because you've already watched the videos, and then, by doing that you will become active during the discussions in class"* (P5$_{2017}$)

The participant shows videos can be replayed to improve one's understanding, and that understand in turn helps in classroom discussions where engagement with content is dealt with at a deeper level.

Hybrid nature of the course

Participants learning experience involved exposure to both online and face-to-face learning. Their views were sought through the question: Question 3: *How would you describe the way the course was delivered in general?* Findings for this question revealed three educational aspects: (1) *strategies for developing critical thinking*, (2) *time constraints*, and (3) *instructional benefits associated with videos*. The third finding can be seen in the following quote from one of the students.

> *"The <u>video was helpful</u> in a way. That I could watch it and then if there is a point where I don't understand <u>I can pause and then read</u>. I <u>played it until I can understand more of what I have read</u>, unlike when in class, you just say something then if I didn't hear it correctly then there's no way I can get it back so in the video <u>I can go back to the video</u> and <u>then play it again</u>. So in a way it was helping with my studies. <u>I can go back and watch the video more and over until I am able to answer the question that I was instructed to</u>"* P7$_{2017}$).

Thus part of the benefits indicated in the quote is that videos can be replayed at any time until one understands the content. Videos form part of the hybrid component of the instructional process of the course.

Post-classroom learning support

FCA has three phases: pre-class, in-class and post class. The post class phase serves to consolidate what has been studied during the in-class phase, while the pre-class phase serves as preparation phase for what is going to take place during class time. Obtained participants' views were guided by the question: Question 4: *Was there any assistance or extra help you could get after class regarding some things you may not have understood during the in-class session? Please explain.* Three key ideas emerged as findings for the question: (1) *personalised and learning from others*, (2) *strategies for interactive engagement*, and (3) *overstretched workload*. Personalised and learning from others involved sourcing out additional videos on YouTube to improve understanding of content taught in class, as well as consulting with group mates, friends, other peers or the instructor. Strategies of interactive engagement involved group work and its dynamics, such as selection of members, ensuring collaborative work, group participation in class where all members had to actively participate, dealing with members who do not come to class prepared, and where necessary instituting punitive measures to those unwilling to participate. Overstretched workload entailed additional courses belonging to the same degree programme. Some of the key ideas listed are indicated in the quote provided below.

> *"The only help that I sought in this module was when I was approaching to write the test or the exam, because I am doing a lot of modules, and I have a lot of work to do academically. So, but yeah I got help from my friends where I couldn't understand some of the concepts in this module, and then I got some assistance. I checked for other questions, related questions on google, and some videos on YouTube and also I got some questions in the prescribed book"* ($P6_{2017}$).

The underlined segments show aspects of personalised and learning from others, as has been described earlier on.

Classroom interactions

Classroom interactions take place within the face-to-face learning environment where content is discussed at higher cognitive level. Evaluation of how the classroom activities progressed from participants’ perspectives was obtained through the guiding question: Question 5: *How would you describe the classroom interactions during the face-to-face sessions?* The interview findings of this question revealed an important theme identified as *strategies for interactive engagement*, characterized by other seven sub-themes, namely: *peer teaching, pre-class preparation, developing subject interest through interactions, disclosure of misconceptions, group presentation evaluations, physics problem solving strategies and problems associated with large class size*. An example of some of the listed sub-themes are identifiable in the quote below from one of the participants.

> “*It is very good because we learn a lot of things. We learn to interact with other students, and communication skills, how to use the ideas from one another. And let’s say someone raises an idea, so we or us, as a group, we discussed that idea, we learn communication skills, and how to interpret what was the misconception of that individual. We teach each other as a group. It helped us to discover a lot of things through group discussions”* ($P8_{2017}$).

The quote shows some of instructional strategies, such as peer teaching, group work, and disclosure of misconceptions, which help to improve conceptual understanding under the supervision of the instructor.

Teaching-learning materials

Teaching-learning materials help establish a dynamic learning environment, where there is variation of activities and potential for progressive learning. To gain an understanding of how participants viewed the learning resources employed during the instructional process, participants were questioned: Question 6: *How would you describe the teaching and learning material used during the course of the semester for this module?* Four major themes emerged from the data obtained: (1) *accommodating students’ different learning styles*, (2) *video-distributed content preferences*, (3) *reference material preferences* and (4) *challenges with BLMS*. *Accommodating students’ different learning styles* reflects participants’ appreciation of how the instructional approach takes into consideration the different learning styles of the students involved. *Video-distributed content preferences* reflects participants’ expectations, where participants preferred the inclusion of certain learning aspects when compiling information for dissemination on videos. These considerations include – videos of short durations, videos showing demonstrative experiments and calculations, and detailed information on some concepts. *Reference preferences* entail providing more reference sources as alternative reading material to video watching. *Challenges with BLMS* reflects difficulties participants encountered when trying to access video material, where blackboard system was not working at times, and video distribution had to be done manually-a process also which had its own inefficiencies. The quote below shows some of these learning aspects.

> *"Alright, teaching and learning resources, they tend to enable different students who learn differently. Therefore having videos it allows the visual learners and auditory, than a having the material like as a document or a book, it allows other students who learn by logical thinking, and so therefore, I think that it tends to, the approach tends to cover learning styles like, if you don't get it through watching the video you can get it through reading, you can get it through hearing, you can make it in that way. The approach itself it makes it easier for different types of learners who learn differently . . . But then with the video the disadvantage it can be that you find that the video it is too long. The video is too long and then at some point you get bored . . . Alright with this one I think videos they cannot have all aspects at once. So at some point when you watch the video, then after you read a document you can find that this thing it is related to the topic which we are discussing but it is not in a video because the video, it's like someone is teaching you. At some point he might not touch all the aspects which you are perceiving"* ($P5_{2017}$)

The participant appreciates the instructional benefits that comes with the approach, where the underlined sections of the transcript show addressing of different learning styles, how long videos end up boring the person watching, and that videos do not contain all information needed, hence the need for alternative reference sources.

Examination preparation

It is through various learning experiences students are exposed to, that they are able to prepare for their final semester examinations. Participants were asked for information regarding their level of preparation: Question 7: *How prepared were you for the end of semester examination after going through the module?* Two major themes emerged as findings from participants' responses: (1) *exposure to enabling learning environments*, and (2) *time constraints*. Under *exposure to enabling learning environments*, it was noted participants acknowledged the instructional approach had impact on preparation for examination since they were subjected to different instructional strategies, which led to better performance in the examination. In their view, tasks or questions discussed in class were difficult, which in turn helped them prepare for their physics examination. Group and open-class discussions provided them the opportunity to exchange ideas. Specific group allocation of tasks helped them to pay attention to the detailed presentations from other groups during open-class discussions. However, there were as well feelings of irresponsibility where some students failed to pay attention to these open-class presentations, because they felt the task had not been allocated to them. Their understanding was to focus only on the task given to them, which disadvantaged them in terms examination preparation. The situation was compounded by an unwillingness by some members of other groups to share their information once they were out of the classroom situation. *Time constraints* entailed lack of time to adequately indulge in revision of course material due to other academic demands. Some of these issues can be noted in the quote from one of the participants:

> *". . . You learn them from asking questions, you learn from hearing what other students are saying, what the whole class is saying, even the inputs from our instructor. Therefore, you find that when you leave the class you have learned a lot of things, because during the discussion you get to note down a lot of things, then, before you can even realise it you have wrote a lot of things down and then, when going to exam, you just only go through the notes which you took from the class. Then it becomes easier for you to prepare for the exams. Something which you were actively engaged in during the interactions becomes much hard for you to forget it during the examination. So it made real impact on preparing me for the exam"* $P5_{2017}$)

The participant acknowledges the usefulness of class discussions when it comes to exam preparations.

Limitations of the instructional approach

Despite positive aspects associated with any instructional approach, there are always some limitations that negatively affect the level of success of that approach. In this study, students were interviewed to determine what they thought were the weaknesses of the instructional approach: Question 8: *What were the weaknesses of the instructional approach you experienced?* Three major themes emerged from analysis of the participants' responses: (1) *video influence on class discussions,* (2) *unproductive class discussions,* (3) *workload related time constraints*. In view of participants' responses, *video influence on class discussions* was in two parts. Watching videos prior to class meetings led to productive class discussions. However, there was also a dissatisfaction that the video content was not at adequate depth to address some of the questions at higher cognitive levels discussed in class, as well as quizzes and tests. Some of the videos were considered too long even to watch as well. In this regard, issues were regarded as weaknesses limiting the effectiveness of the instructional approach. The second theme talks about *unproductive class discussions*. The finding is about students who fail to live up to the expectations of conducting robust and sound academic arguments. These limitations entailed: inability to articulate meaningful questions without confusing others, students who are not attentive to what transpires in class, students who are simply interested in basic information while others sought detailed explanations of concepts, pre-conceived perceptions that physics is difficult thereby investing little time into it, inability to interpret what a physics task is talking about due to lack of appropriate background knowledge and technical language limitations, and a large class size resulting lecturer not being able to attend to individual needs of many during class time. These issues without being properly addressed lead to unproductive class discussions. The third element is *workload time constraints,* which refers to demands from other modules of the same programme, where student had a total of six or seven modules, thus leaving them with very little time to focus on their physics module. Some of these issues are shown the quote provided below:

> *"Oh, this approach of learning sometimes it becomes challenging because you find some of the learners try to ask certain questions that leaves you more confused about what answers you should give to their questions with the information you had before. So the instructor himself tries to clarify the question, while there are some learners that are not listening. So it become challenging because you are not aware of what you are doing. Like when the instructor is asking the questions, he asks the question 'why', what does it mean, and some of us or some of learners are not interested in the how part and the why part. They are only interested in the basic things sometimes. But those learners who want to know more about the why part, the teaching approach becomes more useful to them"* (P8$_{2017}$).

The quote shows situations (underlined) that maybe encountered during class discussions that negatively affect the effectiveness of these discussions.

Sequencing of course units

Better presentation of content entails sequencing of content in a particular way in order to improve student's understanding. Participants' opinion about the order of arrangement of the course units were sought through the question: Question 9: *How would you describe the way the main ideas in the topic of geometrical optics were sequenced?* One central theme came up from the analysis of their responds: *ray model plays a central role to the study of behaviour of light in all medium*. The overall sentiment was that ray model is fundamental to the study of refraction and reflection of light. The sequencing of course units used to deliver the course made sense. The teaching of ray model at the beginning of the course enables ray-tracing techniques to be used in other areas of geometrical optics. Any deviation to original sequencing of course units would create confusion in students. However, contrary to other participants' views, one of the participants preferred that reflection be taught first instead of refraction, and justified this position saying reflection is easier to understand than refraction, and also that it was the order followed in the prescribed textbook. Some of these views are reflected in the quote given below.

> *"No I wouldn't. The way the arrangement was, I think was very fine because I could relate from ray model, I could see the relationship when we go to the refraction and then when we go also to reflection. I don't see any problem with the arrangement of the movement"* ($P6_{2017}$).

> *"Ok. If it is reflection before refraction, from the way I see it, or the way I saw it, the reflection was easy to understand than refraction. So that's the way I preferred, the reflection before the refraction because. I was able to relate my knowledge of reflection so that I can use in refraction to understand it better"* ($P7_{2017}$).

The two interview quotes reflect different opinions but only on what to study first, reflection or refraction, whereas the arrangement of course units started with ray model, then refraction, and lastly reflection.

Laboratory experience

Laboratory experience is a crucial component in the study of science. This is where theory studied in class is exemplified in real-life experiences. After exposure to laboratory experimental learning environments, students opinion about their experience were sought using the guiding question: Question 10: *How would you describe your experience with laboratory activities?* The main idea deducible from participants' views was *learning through* ex*periment.* The view of the participants was that laboratory experience brought a feeling of really studying science. Unfortunately they were not able to do as much experiments as they wanted due to shortage of some equipment for certain experiments, and time constraints as well. Despite the setback, participants found the theory studied in class very useful in guiding them on how to conduct the laboratory experimental investigations. Some of these views can be noted in the the quote from one of the participants:

> *"Yes, OK, the laboratory sessions or can I say the practical part came after being exposed to the theoretical part. So it was easy to go to the laboratory and perform that experiment*

because we have knowledge about whatever that we could be doing. So, it was not that difficult because you know that if you shine a light then a ray comes. A ray is shown there, you know from your knowledge of the theoretical part what that means rather than just doing something without any background information about it" ($P7_{2017}$).

The participant values the role played by theory studied in class as it served as background information without which would make it difficult to conduct the laboratory practical. How important it is for students to get laboratory experience can also be noted in another quote from one of the participants:

"When we teach this module, we should consider doing the practical. We should have all the apparatus, do we call them apparatus, everything that is needed so that when we learn, when the lecturer tells us this and that, we should see it happening somewhere. Because as I am an educator and a student teacher I find it difficult for me to do the practical of light when I get to school since I didn't do them here. I can't learn them there. I should be taught first before I teach other learners" ($P6_{2017}$).

The participant expresses the importance of linking theory to real practice, for this has life-bearing consequences, as exemplified in future professional implications as an educator. Thus laboratory practical serves to make theory realistic.

Changes that were made to the 2017 intervention design took into consideration negative issues raised by students (see section 4.4.2). The instructor designed videos tailored to the needs of the students. This was to address concerns about lack of adequate information on videos downloaded from websites. Worksheets with questions covering different aspects of the content were provided to students as a way of addressing the need to work on many problems in class, as well as the need for covering all content aspects. The worksheet made it possible for students to be exposed to many problems for practice sake, forced them to read more material seeking for information on various aspects of the content. Class presentations were subjected to questioning by other students and instructor forcing students to provide answers supported by reasoned arguments. This was an attempt to address concerns raised about students who made poorly researched class presentations. The instructor got more involved in laboratory activities than in the previous years, especially in in the design of experiments and investigations, while technicians made sure the actual laboratory activity took place. This activity was conducted to address the need to bring awareness to the student how theory studied in class had a practical meaning in real life. These modifications were additional to those made to the previous intervention of 2016.

4.5 MICRO STUDY OF 2018

4.5.1 Quantitative results from the modified SALG survey of 2018

4.5.1.1 Profile Data of Respondents

The study had the highest number of participants (146) compared to those of 2015, 2016 and 2017. There were more males 102 (69.9%) compared to the females 44 (30.1%) as indicated in Table 4.17.

Table 4. 17: Demographic Profile of the Respondents

Variable	Category	Frequency (N)	Percentage (%)
Gender	Female	44	30.1
	Male	102	69.9
	Total	146	100.0
Age	18-19	-	-
	20-21	64	43.8
	22-24	63	43.2
	25 and above	19	13.0
	Total	146	100.0

The number of the respondents was almost the same for the age groups 20-21 and 22-24, with 64 (43.8%) and 63 (43.2%) respectively. A few participants 25 years 19(13%) and above. There was none in the 18-19 age group.

4.5.1.2 Reliability Analysis

The total number of items analysed before any adjustments were 34. The Cronbach's Alpha value was $\alpha = .953$. Item-total statistics revealed three items with mean values too low than the rest of the other items. In addition, these three items were not adequately addressed during the instructional delivery process due to time constraints. As such the items were excluded from further analysis that took place with the other items. The Cronbach's Alpha value slightly dropped to a value $\alpha = .952$ after the exclusion of the three items. Still the questionnaire was regarded highly reliable with 31items.

4.5.1.3 Suitability of Data for Factor Analysis

The data was tested for its feasibility for factor analysis by calculating the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett Test. The value of KMO was found to be .920 and the Bartlett's test of Sphericity had a Chi Square value of 2685.971 with significant value 0.000 as shown in Table 4.18.

Table 4. 18: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.920
Bartlett's Test of Sphericity	Approx. Chi-Square	2685.971
	df	465
	Sig.	.000

4.5.1.4 Factor Extraction

From a total of 31 variables analysed, 6 variables had Eigenvalues greater than 1, and a cumulative variance of 64.9%. Table 4.19 shows the 6 variables identified as components in the first column. Thus, according to the Eigenvalue criteria there are 6 major themes or underlying latent factors that can be identified from this data.

Table 4. 19: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.88	41.55	41.55	12.88	41.55	41.55	4.18	13.48	13.48
2	2.05	6.61	48.16	2.05	6.61	48.14	3.67	11.84	25.32
3	1.57	5.05	53.23	1.57	5.08	53.23	3.31	10.69	36.01
4	1.44	4.65	57.88	1.44	4.65	57.88	3.09	9.98	45.98
5	1.13	3.66	61.54	1.13	3.66	61.54	2.98	9.61	55.59
6	1.04	3.34	64.87	1.04	3.34	64.87	2.89	9.28	64.87
Extraction Method: Principal Component Analysis.									

4.5.1.5 The Scree Plot

The Scree Plot Figure 4.4 shows the Eigenvalues plotted against all the 31 variables in the questionnaire. It was used to verify the number of components extracted using the Eigenvalue criteria. The number of components extractable from the data set were the number of plots on the graph above the horizontal line drawn passing through the value of 1 on the Eigenvalue scale. Alternatively, a straight line drawn along the plotted curve starting from the last variable end until the point where the graph starts to curve upwards left 6 points. These points were considered as the number of principal components being sought.

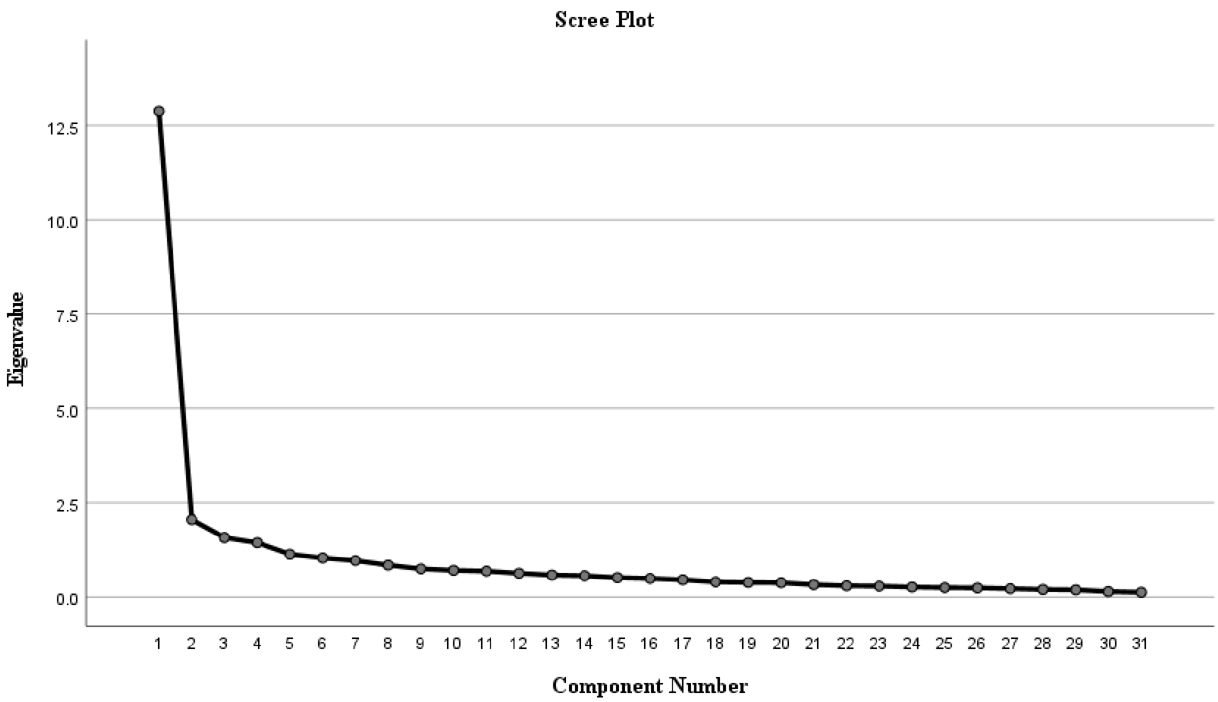


Figure 4. 4: Number of components extractable from the 31 variables

4.5.1.6 Naming the Factors

Factor rotation technique in SPSS was used to identify factors where variables loaded the most. Table 4.20 shows six factors extracted using the FA method. The cluster of variables for each factor are the column with the heading labelled factor attributes, and each cluster was used to identify the underlying theme associated with a particular factor. To come up with meaningful names for the factors, the top one or two loading items in that cluster were used. In Table 4.20 the three topmost loading items for factor 1 were used to identify the name of the factor. Thus Factor 1 was associated with student participation in class, hence was named *participation in class discussions*. Similarly, the other seven factors were named using the same technique.

Table 4. 20: Names of factors (derived from attributes and factor loadings) that influenced learning in participants of 2018

Factor 1	**Factor attributes**	**Loadings**
Participation in class discussions	Listening to discussions during class	.762
	Participating in group work during class	.733
	Participating in discussions during class	.699
	Presentations by group representatives after discussion of problems in respective groups	.620

	Your willingness to seek help from others when working on academic problems	.551
	Distinguishing between ray and wave models of light	.527
	The order of priority used to discuss main ideas of the topic	.498
Employing strategies that encourage collective active participation in class discussions on key geometrical optics ideas when solving complex problems: mean = .627		

Factor 2 Knowledge and application of ray tracing techniques based on ray model of light	Using the ray tracing method to locate the image position of an object placed a specified distance from a lens	.739
	Using the ray tracing method to locate the image position of an object placed a specified distance from a mirror	.719
	Stating and using the key ideas outlined in the ray model of light	.611
	The feedback on my work received after tests	.528
	In the way this module has been taught compared to the way your previous physics module was taught	.488
	Distinguishing between mirror and diffuse reflections	.402
Developing knowledge and abilities of ray tracing techniques based on the ray model of light: mean = .581		

Factor 3 Building self-confidence to take charge of own learning	Confidence that you understand geometrical optics	.747
	Feeling at ease when working with complex problems in geometrical optics	.679
	Your confidence to write the final examination	.608
	Enthusiasm for the subject of physics	.565
	Your interest to learn more of geometrical optics	.518
Allowing students to take charge of their own learning by developing interest and confidence for solving complex problems: mean = .623		

Factor 4 Knowledge and application of the laws of geometric optics	Describing what happens to speed, frequency and wavelength when light goes from one medium into another	.756
	Using Snell's law to predict the path of a light ray as it moves from one medium into another	.646
	Applying the ray model, geometrical optics laws and principles in solving problems	.548
	Describing the operation of optical fibres using total internal reflection	.492
	The feedback received from the instructor on questions posed during class discussions of content	.403
Developing and applying knowledge of concepts, laws, and principles of geometrical optics for solving complex problems based on students' feedback from questions posed during class discussions: mean = .569		

Factor 5 Video based learning activities	The quiz written after watching each video presentation	.707
	Video presentations posted on blackboard by the instructor	.664
	Reading material recommended by the instructor	.564
	The level of difficulty of the problems discussed in class	.456
Encouraging students to watch quiz-motivated video materials and reading materials recommended by the instructor for solving complex problems in geometrical optics: mean = .598		

Factor 6 Knowledge and application of the mirror/lens equations	Using the mirror equation and sign convention to determine the position, magnification and size of the image formed by a mirror	.735
	Using the lens equation and sign convention to determine the position, magnification and size of the image formed by a lens	.723
	Distinguishing between the roles played by the mirror, lens, and screen in image formation	.607
Developing knowledge and skills needed for solving complex problems using key geometrical optics ideas: mean = .688		

In summary, the key factors that influenced student learning were those associated with:

1. Employing strategies that encourage collective active participation in class discussions on key geometrical optics ideas when solving complex problems
2. Developing knowledge and abilities of ray tracing techniques based on the ray model of light.
3. Allowing students to take charge of their own learning by developing interest and confidence for solving complex problems.
4. Developing and applying knowledge of concepts, laws, and principles of geometrical optics for solving complex problems based on students' feedback from questions posed during class discussions
5. Encouraging students to watch quiz-motivated video materials and reading materials recommended by the instructor for solving complex problems in geometrical optics
6. Developing knowledge and skills needed for solving complex problems using key geometrical optics ideas

4.5.2 Qualitative results from the modified SALG survey of 2018

The following lists are summaries of perceptions related to the strengths and weaknesses of the intervention.

Strengths of the intervention associated with the content

Among the positive remarks noted from the responses was the fact that:

- Students developed interest in the topic by the time teaching ended.

Weaknesses of the intervention associated with the content

- Where content was not clearly understood by students, extra lessons should have been conducted such as in mirrors, optical fibres, total internal reflection, ray model, lenses, the ray, wave, and photon models.
- Time available to students and instructor was not enough to cover all the content in the curriculum even though an attempt to cover it was made.
- An attempt should have been made to balance theory and calculations because much of the content dealt with in class focussed on conceptual understanding.
- Students' conceptual understanding could have been enhanced by providing them the opportunity to do more of hands-on laboratory practical work, where student can observe,

record, analyse, and pass judgement on scientific information, as well as developing their interest in scientific matters.

Weaknesses of the intervention associated with assessment

- The level of subject language used in the questions makes it difficult to understand the demands of the question since students are used to simple English.
- When setting formative tests, the instructor did not mix Multiple Choice Questions (MCQ) with free response short or long answer questions to cater for different student interests.
- The instructor failed to provide a specific scope on what was to be assessed whenever we wrote a quiz or formative tests.
- Most of the questions that featured in formative tests did not involve calculations but were mostly conceptual examining students' level of conceptual understanding. This did not auger well with them. Students considered questions requiring them to perform calculations as necessary to test their ability to apply their conceptual knowledge, while conceptual ones requiring students to provide explanations were regarded as testing content which is hard to master. They preferred a mixture of both or more of calculation type than theory type for that would help them perform better in the tests.
- Students were not able to interpret what a question or problem being solved wanted them to do, especially where the question may involve more than one step. Students' capacity to interpret was limited to what they read in basic materials given to them such as video materials. Sometimes an explanation given in class for a particular situation is wrongly applied to test question.
- The reason they found questions difficult in tests and quiz, and were not able to answer them, was because the questions were not assessing what was discussed in class. The questions were demanding more than what was discussed in class or offered in their course outline.
- The reason why they found tests to be difficulty were because there were more of calculations in class than theory, while tests tested more of the theory than involving calculations. Thus, tests were not in line with what was taking place in class.
- Students preferred questions to be sourced from prescribed books believing that approach would make the situation easier for students.
- The reason why they found the test difficult were because the tests were MCQ type
- A quiz must be written after the concept was taught in class.
- A quiz should not be based on the video material posted on blackboard but on the content itself. The argument being that if someone did not watch the video, that does not mean they

don’t know the content, while others were of the view that the quiz should strictly ask for knowledge presented in the video material.

- The number of assessments be it quiz, or tests were not specified at the beginning of the semester to help them with planning and study thoroughly.
- The quiz and video material were not of any help because they did not help them to answer the questions in the test. Quiz questions were supposed to help students answer the questions in the tests. The videos were not helping because the questions the lecturer asked were nothing from the videos. They would study the video material and understood it, but tests would come differently. Thus, the tests seemed to have many things that are new because they were accustomed to focus on the given video materials, which did not have all the information.
- Students found it difficult to use diagrams in physics in questions that required them to do so. They preferred questions that need no use of diagrams as part of the response.
- Students did not feel at ease to work with complex problems in geometrical optics because the instructor demands students to provide a lot of information than what they could provide in the answers expected of them, making it difficult to work with complex problems.
- In general assessments were not fair to students because they demand a lot from them more than what students expected.

Weaknesses associated with feedback

No positive sentiments but students felt strongly about the following:

- Feedback provided by the instructor was inadequate without students being given their scripts back, even though the instructor revised the tests with students, and students were allowed access to the scripts most of the times. Students felt being not in possession of their scripts disadvantaged them somehow.

Strengths associated with video material

- The use of video material was greatly accepted because the material enabled students to study at their own pace, at any place of their choice, and at any time, and so the material was considered very helpful.
- The material could also be used as revision study material for preparation of tests and examination. The fact that the presentation on the material usually focuses on one topic only was greatly appreciated for this was considered to make study easier.

- With the right content placed on video material, there should be no need for class discussions

Weaknesses associated with video material

- The video materials did not include much of sample problems meant to guide students on how to respond to questions or perform calculations of a certain type of problems.
- The video materials did not help much because it did not contain information deep enough to answer questions or problems on quiz and tests. The questions on tests were not set based on videos.
- More video materials should be made available to students provided they have right content useful to students.
- Quiz should be about assessing the content regardless of the source from which it was studied, rather than basing it only on the video material provided to students.
- Video material should not be made available to students for the sake of preparing for face to face in class activities, instead should be made available after the lesson for consolidation of what was done in class.
- Video materials lacked a summary of what was presented on it.
- On some video materials concepts were not well articulated making it difficult to understand the material.
- Use video material prepared by different people but on the same concept.

Strengths associated with class discussions

- Activities helped a lot to address misconceptions held by students.
- Students learned a lot from presentations than having lectures. Moreover, presentations cover a lot of content in a short period of a time

Weaknesses associated with class discussions

- Discussion groups worked on different questions assigned by the instructor, an idea that was not welcomed by some of the student participants. If group activity was assessed, the assessment becomes unfair since the questions had different levels of difficulty, implying some groups put more effort into their work than others.
- Some discussion take more time focusing on one concept. This affect the pace at which the topic has to be covered. The need to improve time management.

- The instructor needs to explain fully during the lesson as this has implications when coming to answer questions in tests and examinations
- Where similar questions were prepared by different groups, it was not fair to let only one group present and questions are asked to the rest of the other groups.
- The instructor should provide more problem sets involving calculations for discussion for students to have adequate practice and be prepared for examinations.
- Instructor should consider that there are students who prefer to work without the company of others and group work tend to inconvenience them.
- The instructor should introduce the lesson by a brief explanation of areas where students have difficulties.
- Class presentations may work for other students but that should not be assumed to be the case for all students.
- Rather than starting with discussions in class, a mini lecture is advisable since some of the presentations on video materials are not well understood.
- The instructor should provide problem solutions after class for the set of problems on worksheet discussed in class.
- The instructor should provide a summary of key ideas for each discussion done in class because when students answer questions in their groups, sometimes the answers they provide during their presentations are misleading, and it is difficult for students to rectify that on their own.
- The instructor should desist from doing away with lectures but prepare lesson presentations and present them, instead of relying on group discussions, whole class discussions or presentations by students.
- There must be a way of managing group work where different tasks are given to different groups, for some students do not take group work seriously and only focus on their given question. They do not pay attention to what is presented by other group during class presentations.
- It is preferable that all groups should try all questions on the worksheet, other than being given one question, so that during presentation groups are chosen at random. Some students are lazy and let others work for them since they know it's the only question they can be asked to present.

Strengths associated with guidance provided by instructor

- There was a strong focus on how to analyse concepts and distinguish them

Weaknesses associated with guidance provided by instructor

- Graded activities needed to be specified when they could be written so they could be planned for
- There is need to develop student interest to participate in class discussions by showing them how to answer questions of different cognitive levels, during class discussions.

Strengths associated with the instructional approach in general

- The method of delivery of content was entirely a learner centred approach, and instructor was encouraged to continually use it with other students
- The instructor's method encourages students to go and prepare and come back to class and discuss while he asks questions. The method helps students to discuss any confusion raised from the video material.
- The approach requires students to apply what they know through real life related physics problems discussed in class.
- Students are encouraged think before they answer a question because they are always expected to support the answer by providing reasons for saying so.

Weaknesses associated with the instructional approach in general

- Instructor should lecture rather than using the videos or presentations, he does not use the video material to set for examination
- There should be extra lessons because students have other modules they have to focus on, and the workload of all the modules is heavy but the time is short.
- Time management was a problem for students because it was difficult to move at the same pace with the instructor.
- Though the approach is good because it saves time, but it allows students move fast without understanding the content in depth.
- The instructor should take into consideration learners that have difficulties in grasping concepts quickly

Weaknesses associated with learning materials other than video materials

- Students tend to focus only on video material as key study material if not constantly reminded and directed to use the prescribed textbook, some even came to think there was no textbook that was prescribed.

- To augment information presented on video materials, provide slides with additional problems for practice.

Strengths associated with the instructor

- The instructor as facilitator was fair, motivated students and encouraged independent learning. with everything throughout the whole semester

Weaknesses associated with the instructor

- The instructor gave students a lot of work, demanded a lot from students, the subject itself was difficult by its nature, the lecturer failed to take into consideration that students did not have the same knowledge about the content as compared to himself.
- The instructor should be motivational when introducing content to counter negative attitude towards the subject itself, created out of work overload.
- The instructor should prepare class presentations and provide lectures since he knows his subject matter very well.
- The instructor should encourage students develop ability to discover things by themselves by building the right attitude.

Strengths associated with post class activity

- After class activities motivated students to learn more on their own rather than always leaning on the lecturer

Weaknesses associated with post class activities

- Students need more time to study and to go through the videos
- More learning activities should be given to improve student understanding, but the work should not contribute to students' coursework mark.
- More practice problems should be given often than quizzes to build-up real-life understanding

The themes grouped in the previous section were summarised according to Table 4.21, which shows the theme, the number of times it was mentioned, and that number expressed as a percentage. The theme that was highly mentioned was about issues related to assessment (30%), then followed by issues related to class discussions (16%). In third place were issues related to the study of the content (12%) while ranking fourth where issues related to video materials (10%) and the instructional strategy in general (10%). At the bottom of this list are issues related to guidance

(3%) provided by the instructor and the influence of the lecturer (3%). Details of what these issues were about were summarised in the previous section under strengths and weaknesses of the intervention. Those issues were grouped either as strengths associated with the theme, or weaknesses associated with theme, or might appear in both classifications as key ideas of the issues identified under that particular theme. The percentages in Table 4.21 reflect how strongly the participants felt about those issues, which could be positive sentiments or negative sentiments. The higher the percentage the stronger the students felt about that issue, while the smaller the percentage, the less the students felt about that issue.

Table 4. 21: How strongly participants felt about each educational aspect identified thematically

Code	Theme	Count showing how many times a theme was mentioned	Count expressed as a (%)
1	Content	27	12
2	Assessment	67	30
3	Videos	22	10
4	Feedback	13	6
5	Class discussion	36	16
6	Guidance	7	3
7	Instruction	23	10
8	Other learning material	10	4
9	Lecturer	14	6
10	Post class activity	7	3
	TOTAL	226	100

4.5.3 Interview results of the study of 2018

There were three student participants selected for interview in this micro study of 2018. They were selected using the same criteria as was done in the previous years – considering high, middle, and low performers. This section focuses on findings of the interview for all questions on the interview protocol (see Appendix G). The opinions of the three interviewed student participants were examined based on all questions on the protocol. Findings from the interview data obtained from the three participants are listed in accordance to the underlying themes directly deduced from each of the ten questions on the interview protocol (i.e. question-based pre-deduced themes).

Content level difficulty

Participants were questioned on how they perceived the course content in general, as guided by the question: Question 1: *How would you describe the content you learned in this course?* Their responses raised three major issues (themes): (1) *content interesting and comprehensible*, (2) *subject specific language difficult to understand*, and (3) *video challenges*. The first theme, *content interesting and comprehensible*, was understood by participants as not too difficult to understand, and the fact that it could easily be related to life experiences made it interesting. The second theme *subject specific language difficult to understand* showed that though the content was comprehensible, the technical language sometimes employed in studying the subject and used in the assessment task was difficult for the participants. The third theme *video challenges* showed that, some sections of the content presented on videos was done using language that was too technical, which made it difficult to understand the explanations presented, and as such expectations were that the videos would be watched again in class in order to explain the difficult areas.

> *"So to me it was not too difficult. It was interesting. It was not too easy and it required a lot of thinking"* (P9$_{2018}$).

> *"OK, what can be done is the lecturer must bring those videos in the class. Because there are some concepts or some words that we don't understand and we need clarity. Even if we can play back the video. So what can be done is that the video is brought in the class and we watch the video and where we don't understand, the video is paused, we ask questions, what about this, what about this, what about this, what about this. I think that would make us understand the concept. Because we watch the video alone, even though the videos are explained, but somewhere they have to be brought in class where we have discussion about them or on them . . ."* (P10$_{2018}$)

Because of the technical language in some areas of the content presented (see underlined sections in the quote) in the videos, the participant felt it was necessary to watch again the videos in class. Thus subject language is a factor that determines student understanding of the content.

Ability to solve physics challenging problems

Participants were exposed to various tasks throughout the semester, after which they were asked about their ability to solve physics problems: Question 2: *How did the instructional approach influence your ability to solve challenging problems in physics?* The key issues that emerged from their responses were: (1) *strengths and weaknesses of videos*, (2) *strengths and weaknesses of the overall instructional approach*, and (3) *quiz assessment expectations*.

On *strengths and weaknesses of videos*, participants pointed out how videos can be easily played and replayed at any time, whenever one wants to recall some concepts, and can be done anywhere. This was taken as some of the strengths or advantages of using videos over other teaching media. On the other hand, there were some issues they considered as weaknesses associated with the use of these videos. These included: not all students were watching the videos because they were not used to do that, but regarded them simply as additional material to support what is taught in class instead of introducing new concepts. Thus there was no urgency to watch them before class as they could watch them after class. Another issue was that the videos did not include demonstrations on how to answer certain problems or questions, or did not include exercises or additional exercises in some cases for further practice. Participants also found it difficult to understand certain concepts presented on videos.

> *"OK. I think the videos develop our ability to solve problems because, in most cases, with the videos, if you don't understand something you can play it back again and again and again, until you understand the thing that you have been taught. And the other thing is, there are some few activities that are given in the video, where the instructor or the person who's teaching in the video shows us how to solve those problems. And the advantage or what makes us to understand and be able to apply what is taught in the video, it's you can always go back to the videos and watch if you didn't understand. And then the ability to solve those problems can be enhanced. Even if you don't understand the activity in the class you can always go back to the video and refer, and do what was done in the class alone, watching at the video"* ($P10_{2018}$).

In terms of *strengths and weaknesses of the overall instructional approach*, the positive aspects appreciated included- mechanism for recalling easily basic concepts thereby enabling a positive attitude towards the subject to develop, strategies that were in place to make every individual accountable for their work thereby encouraging participation, concepts were described diagrammatically and mathematically thereby enabling development of the ability to solve complex problems.

> *". . . on Snell-Descartes's law, where this law was described mathematically and in the form of a diagram, where if someone explains a concept using a diagram, you can easily form the picture of the concept, to say this concept is related to this diagram, the diagram is going to give it a practical part impression to show where can you, or how can you apply*

the concept in real life situation. So if you can do that, then <u>you can be able to solve any physics problem under geometrical optics</u>" (P11$_{2018}$).

However, the weakness side was that some participants viewed the approach as suitable for high achievers only, since the instructional approach was unfamiliar to most students.

With regard to *quiz assessment expectations*, in participant views there was need to develop an awareness of the purpose of the quiz assessment in order to enforce all students to watch the videos prior to class meetings. It was also suggested that formative tests based on video content only be given, or the quiz assessment should include open-ended questions to avoid guessing of answers.

> *"I think the better way to solve this problem is, when we are given videos, <u>the lecturer must tell us that go and watch the videos</u>, and <u>we are going to have a formal assessment task</u> tomorrow . . . So, and the other solution is that, <u>after every video there must be an assessment</u>, or there must be an activity that is given to us. <u>A formal activity where we sit down and write maybe a test or a mini test or an assignment</u> where we write what we have learned from the videos. Because in most cases, the reason why we don't focus on these videos is because we know that these videos are going to be discussed in class by the lecturer. So we don't have to watch them . . . And then <u>students know that we are going to write a multiple choice. So even if we guess those things, but in those quizzes, we must have open-ended questions</u>, where students will be writing"* (P10$_{2018}$).

These are excerpts of the quotes showing participants' views on ability to solve physics challenging problems.

The hybrid nature of the course

The course design consisted of both online and face-to-face components. Views of participants on this hybrid nature of the course were sought through the question: Question 3: *How would you describe the way the course was delivered in general?* Participant interview responses generated three themes: (1) *feedback learning*, (2) *Time constraints*, and (3) *Experimental investigations*. Participants' opinion showed that *feedback learning* was important as this improved their understanding of the content, and enabled them to successfully answer examination questions. Thus feedback is part of the delivery process which serves to enhance conceptual understanding.

"I think that it was not easy but it was helpful, because when you go and write maybe a quiz or a test, and then you are then helped on how you were supposed to answer or interpret what the question really wanted, or how it was unnecessary to write stories instead of getting straight to the point. I learned to answer the question that is asked, and then we learned to get straight to the point. We learned to give diagrams where necessary, or if possible then to resort to equations and relate principles that we have learned, such things. So I think that it prompted us to think, and then to understand what we are doing, and to answer questions better than what we did before" ($P9_{2018}$).

The second major theme that emerged was *time constraints*. This aspect of learning describes challenges participants had with videos. Among the issues raised include the release of videos when there was not enough time to prepare for the quiz written during class meeting, thus putting participants under pressure and thereby leading them to watch without understanding. The videos needed repeated watching to understand the content, but because they were lengthy, participants ended up watching them once. Because the videos were lengthy, the watching was also tiresome.

"Yes because in most cases we watch those videos under pressure knowing that we are going to use them. And then sometimes these videos we watch them today when we know that tomorrow we have an assessment activity to complete . . . I think the videos must be given in time, may be two weeks before we go into the assessment . . . because you may find out that the video take long duration and you watch them once and then you have to do other academic works, and you are unable to watch them again. And in most cases what I have realised is, the understanding of watching those videos does not come when you watch them once. You have to watch them more than once. If you watch them more than once, that's when you will grasp what is discussed in the video" ($P10_{2018}$).

The third emerging theme which was *experimental investigations* was in two parts. The first part involved participants designing activity of the laboratory experimental investigation as a group, and the second part performing the actual experimental investigation. The general feeling of participants was that the process was very helpful in developing concrete understanding of the concepts studied.

"The manner in which the course was delivered to me <u>was very helpful</u> . . . we were given course outline and the type of the experiment that we should design ourselves . . . this

course was designed in such a way that, <u>we are designing experiments</u>, the lecturer is not designing experiments for us, then to say, <u>go to lab and follow these instructions, and eventually collect data, go out there and write the lab report and submit</u> . . . So I can say that out of this course, what I learnt is that, as a scholar, <u>you should be able to go to read on your own and understand</u> and if you don't understand you should go an extra mile to understand" ($P11_{2018}$).

The three quotes from the three interviewee show how these participants appreciated the hybrid nature of the course. Even though there were time constraints that put them under academic pressure, the design nature of the course promoted understanding of the content.

Out of classroom assistance

Activities held after class meetings help to consolidate learning that took place during class time. Participants were questioned gain information on how the interacted through the guiding question: Question 4: *Was there any assistance or extra help you could get after class regarding some things you may not have understood during the in-class session? Please explain.* Participants revealed that the main assistance came from *science learning community* within the science department. This community consisted of group mates, the lecturer- who created provision for consultations to help students who had challenges with assigned tasks, personalised learning-where students at individual level would search for more videos on the same content, use of student mentors-students who were chosen by the university section of academic excellence to assist those who had academic challenges, and the assistance of high achievers among the classmates.

"So basically, I did get maybe extra help <u>from my colleagues</u> only and <u>maybe a few consultations</u>. Yeah that was basically it . . . I did get time for consulting in case I did not understand. I would be given the opportunity to come and consult and the arrangement would be made that this time it's OK to consult. <u>If the instructor was busy, he would just create time when we could meet, which could suit both of us</u>. So yes, I could say that where I did not understand or where my colleagues could not explain to a certain extent, I could understand better when I was given that opportunity to consult" ($P9_{2018}$).

"And in terms of <u>extending my understanding</u>, the first thing is I go and <u>look for more videos</u> that will add on to the videos that I have been watching. And secondly <u>there are a mentors at the university</u> whereby if you don't understand something, you approach them

and then they help you. And the other thing, it's we can identify people who actively participate in class or who understand this concept that we are on and are better. So those people after the lecture, we approach them and we seek for clarity. So more videos, mentors, and identifying people who are better during the class interaction, and then approach them" (P10$_{2018}$).

The underlined sections in the quotes, taken from two of the participants, reflect that a community of learners studying science, assisted by their lecturer, were involved in making sure the learning activity after class time continued to benefit students needed help.

Classroom interactions

Different types of classroom activities may be implemented to enhance student understanding of concepts. Participants were questioned on how they perceived these activities: Question 5: *How would you describe the classroom interactions during the face-to-face sessions?* Six minor themes or subcategories were generated from participants' responses and were summarised as *interactive engagement strategies*.

The first subcategory *quiz assessment* reflected how participants felt about the quiz they had to write at the beginning of the class meeting as a way of assessing level of understanding of their knowledge about the video content watched in preparation for the class meeting. The second subcategory was *assessment feedback* which reflects how feedback was used to enhance student understanding after any type of the assessments used by the lecture, be it written assessment as in tests and quiz or oral assessment as in class discussions. The third subcategory is *peer teaching* which involved student-student interactions which participants thought viewed as very productive. The fourth subcategory, *addressing misconceptions,* perceived also as very helpful by participants, involved openly discussing problems participants had with questions or problems through open presentations before class of their findings after group discussions. Even students who were fearful to speak in front of others were encouraged to speak by making them group representatives. The fourth subcategory was *large class size challenges*. Participants' difficulties included failure to capture explanations from other classmates a distant away from them. There were no teaching assistance but only the lecturer who could not be everywhere. For video watching, some students had no computers to download videos and had to go to computer labs to do so, but the students were too many to share the computers at the same time. The fifth subcategory is *BLMS challenges*. These are challenges participants raised when they wanted to access videos on blackboard. Internet was down at times and participants had no way to access blackboard. Alternative approach was manual distribution of videos through group representatives, and this had its own problems where individuals in possession of the videos were at times not available. The sixth subcategory is *time consuming class discussions*, where participants felt though the discussions tried to accommodate most student queries, they ended up dragging too long such that not all what was planned could be covered in class. Some corrective feedback given by the lecturer were given at the end of the session when left with no room for discussion.

> *"The explanations, I can say were very helpful in class. The explanations that we shared among others, like at a group level, where we discussed at the explanations, attaching meaning to them, but when coming to sharing these explanations to the whole class, that is where the problem is, because each group is going to have its own understanding of the explanation and then we are going to discuss to the extent that we all agree. But then, we can only agree, usually we agree if our lecturer can intervene and give us the explanation, giving us his opinion by giving us the acceptable definition or explanation of a particular concept. Then the problem is that we are given the acceptable definition when the class is over, and then we don't have time to critique and analyse why the explanation is regarded to be acceptable by the scientific community, if I can say so"* ($P11_{2018}$).

The quote from one of the participants, through the underlined sections, highlights the concerns participants had during interactive engagements in class.

Teaching-learning materials

Teaching-learning materials are tools used in the process of delivering content in order to achieve the desired learning objectives. These may be human, or non-human objects. Participants' views were sought through the question: Question 6: *How would you describe the teaching and learning material used during the course of the semester for this module?* Four major issues or subthemes that emerged, and were related to the theme under discussion were: (1) *instructional guidance*, (2) *lack of smart gadgets*, (3) *strengths and weaknesses of videos*, and (4) *materials other than videos.* The first issue: *instructional guidance*-Participants were concerned about some material they were given with no adequate instructions on how to use them, the second issue: *lack of smart gadgets*-some students did not have computers, smart cellphones, or tablets which they could easily access blackboard and download videos or other material posted by the instructor. At times the BLMS was down and videos or material had to be manually distributed. This also created other problems such as those charged with the distribution were at times not available. The third issue: *strengths and weaknesses of videos*- in terms of strengths of video material, participants appreciated that instructor videos factored in students' needs whereas those sourced online did not. The fact that instructional approach encouraged participants to also source their own video material from online sources enabled them to enhance their understanding of the content. The issues raised by participants as weaknesses of the videos included-lengthy videos developed by the instructor himself, lack of online sessions to address misconceptions arising from studying video content prior to class meetings, lack of additional questions within the content uploaded on videos, too much content loaded on videos in the case of those designed by the instructor, to instill a culture of reading, videos were supposed to demand students to answer specific questions before they could progress to the next video. The videos were not completely reflecting the nature of the content to be discussed in class in the next class meeting. Participants also wanted the videos to include references for further reading about the same content they had watched. They also wanted videos to include demonstrative experiments to reflect the application side of the concepts being studied. Delays on videos dispatching hindered adequate preparation for the next class. Participants suggested a two-day minimum period for watching the videos before they could be assessed using the class quiz. The last and fourth issue: *materials other than videos*-was about a suggestion to identify physics websites that provide other online materials which participants could use as reference materials.

> *"There was <u>so much information</u>. Sometimes, <u>information that you do not need</u>. There was <u>no provision for explanations where you do not understand</u>. I think that the material was enough, although the videos, <u>sometimes we got the videos late</u>, and <u>sometimes we had delivery problems of the videos</u>, and <u>sometimes it was blackboard challenges</u>, sometimes we would find situations whereby we were expected to write about the content on a specific video. <u>Sometimes you do not have this video</u>, which was issued during the weekend, while you are not around, or <u>you are away from campus, and then you cannot access it</u>, we are told that we are supposed to write a quiz at the beginning of a lesson, and this quiz would be based on this video. So sometimes it's a disadvantage because you are told that it is going to be based on this video and then <u>you do not have a proper phone to download this video</u>, you are only told over the phone and you are away from campus and you are not sure whether this material you have right now would be enough, or maybe in this video there are further explanations that people are going to have advantage over you, and staff like that" (P9$_{2018}$).*

The underlined sections in the quote from one of the participants show some of the issues already explained at the beginning of this section.

Examination preparation

Participants' views on examination preparation revealed three aspects as having played an important role: (1) *benefits of using videos,* (2) *nature of quiz and tests items,* and (3) *material other than videos*. These aspects were revealed through the question: Question 7: *How prepared were you for the end of semester examination after going through the module?* The participants' views on *benefits of using videos* were that they felt confident before they wrote the examination because they were able to constantly use videos to revisit areas already covered during instruction. They could quickly remember and clarify areas of confusion. They were able to prepare for exams whether there university disturbances or not because of the videos. The second aspect *nature of quiz and tests items* helped them to predict the level of demand of the examination tasks. Participants acknowledged the nature of tasks discussed in class and in tests was very helpful in giving them an idea of how the examination would look like. The third aspect talks about *material other than videos* which included books, and worksheets among other, as also having been helpful since these materials exposed participants to different types of assessment tasks.

> *"I think the videos are helpful, because in most cases, you can find out that we have strikes at school, and you no longer go to class where you are normally given- this is what you're going to do, or the lecturer discusses with students. But the videos, even if the academic activities are postponed at the university, we know that we are able to prepare for the exams, even if the lecturer is not there. Those videos help us even if the lecturer goes to the seminars, and workshops, we know that without the lecturer we are able to prepare for the exams, that's how they help us, because in most cases you may find out that people may give you excuses-aah we didn't prepare for the exams because there was a strike, we didn't prepare for the exams because the lecturer was not here – he says he is going for a workshop. But with these videos we are able to sit on our own and prepare for our examination"* ($P10_{2018}$).

> *"They were very helpful because, we familiarized ourselves with the kind of questions that can be asked in the exam, by that I am not implying that the questions that we were answering during the tests, the quizzes came as in the exam, but the questions just helped us to say, this is what is expected from you, and be able to do this and this and this."* ($P11_{2018}$).

The quotes from two of the participants highlight some of the issues (underlined) already explained at the beginning of this section under this theme of examination preparation.

Limitations of the instructional approach

There was one main issue that emerged from participants' responses under this main theme. This was *strengths and weaknesses of videos*. This theme was obtained through the question: Question 8: *What were the weaknesses of the instructional approach you experienced?* Participants revealed an awareness of the *strengths and weaknesses of videos*. In terms of the positive views, participants pointed out that the videos could be played and replayed anywhere and at any time.

> *" . . . I think it's an advantage, because where you could not capture everything that was said in class, and then you go there, you can even rewind it, always focusing on that part that is difficult for you, or you could just view the diagrams whenever you want, and they will tell you how to do that, and explaining every part in detail, . . ."* ($P9_{2018}$).

Videos designed by instructor were tailored to address the needs of the students, hence contained as much information as needed by students. The videos helped one to prepare for examinations, whether there were disturbances or not at the campus. However the weaknesses associated with video watching, according to the participants, was the assumption that whatever was provided on the videos was sufficient enough to study for the examination.

> *"The weakness of this instructional approach is that, it simply tells the students that, if you can watch the video, and get the content the video is delivering, then the content the video is delivering is enough. The students tend to think that whatever the video is giving is enough, they don't tend to go an extra mile to access other sources"* ($P11_{2018}$).

Another weakness was that videos did not incorporate calculations to help show how certain problems may be solved.

> *" . . . Sometimes you just get stuck and you do not know how a certain value was arrived at in the picture. So I think if calculations are involved, they will be properly explained that we are doing this, this is the step, where we are coming, and because of these reasons, so I think it would also be a great help and advantage, . . . "* ($P9_{2018}$).

In addition, dissemination of content on videos was at times delayed, resulting in poorly prepared class meetings. Finally the videos prepared by the instructor were considered too long, causing one to lose interest.

> *" . . . I would say that the disadvantages were that we needed to receive the videos in time before we go for class because sometimes, it's time consuming for some people to watch*

the videos. It's better for them to read than listen to it because they say that it's time consuming. So it's time consuming already taking 45 minutes, because in class we take the same time, 45 minutes and then I go and listen to the video another 45 minutes to listen to the information there on the video. I still need to go further to read. It could be time consuming" ($P9_{2018}$).

The quotes serve to show where participants felt they benefited or did not benefit with regard to the use of videos.

Sequencing of units

The specific order in which the units were studied started with ray model of light, followed by refraction of light and lastly reflection of light. Participants were asked about how they felt about this arrangement of geometrical optics study units: Question 9: *How would you describe the way the main ideas in the topic of geometrical optics were sequenced?* All ideas projected by the participants under this question were classified as *favourable order of arrangement of study units.* Participants viewed the arrangement as favourable. The units were considered to build one upon the other, with ray model unit as the foundational unit which serves to simplify the much complex concepts of geometrical optics.

> *"I think that the way it was, was just the best way. Because I think that we started by wanting to understand what a ray is in the first place. So I don't think it's advisable to start with reflection. We do not know what we are reflecting, or maybe refraction, whereby angles are just involved and everything. I think that the way we started was ok, and the way we dealt with everything, every part . . . So maybe it would have caused confusion if we started elsewhere. Yeah"* ($P9_{2018}$).

The participant, as reflected in the quote, appreciated the way the units of study were organised.

Laboratory experience

Course delivery involved videos as technological component, class discussions for deepening student understanding, and laboratory experience for concretising the theory studied in class. Participants were asked about how they perceived the laboratory experience through the question: Question 10: *How would you describe your experience with laboratory activities?* Three main issues emerged from the analysis of participants' responses: (1) *role of theory in experimental investigations*, (2) *video learning benefits*, and (3) *time constraints*. Under the *role of theory in* *experimental investigations*, the outstanding issue raised by participants was that theory was important at the time of conducting experiments as it helped to reduce confusion in students in the actual procedure of the experimental activity. The theory also helps in the preliminary design of the experimental investigation, which was an activity conducted prior to attending the laboratory sessions.

> *"The content that I learnt in class did <u>help me to master the practical</u>. Because normally, the practical, whatever that we are experimenting on, somehow is just closely related to what we did in class . . ."* ($P11_{2018}$).

The second issue raised by participants was *video learning benefits*. Participants did not provide a direct relationship with laboratory experiments but pointed what they considered as benefits derived from the use of these videos, which were providing information, as well as development of listening and note taking skills.

> *". . . What I can say is that the video approach was very good because it was giving us the basic understanding of concepts <u>and how to listen to someone talking or lecturing and get something out of whatever the person is saying</u>. It gave us <u>the ability to analyse whatever the person is saying, and put it in writing whatever the person is saying</u>"* ($P11_{2018}$).

The third issue identified was *time constraints*. This aspect of learning was not given how it was related to laboratory investigations. Instead participants pointed out their dissatisfaction with time spent on concepts during class discussions, which they considered to be time consuming and depriving other concepts time needed to discuss them.

> *"I think we covered the issue of time, sometimes in class like we spend a long time focusing on one thing that one learner does not understand, and you find that the majority do not see it as a problem"* ($P9_{2018}$).

The underlined sections of the quotes reveals what participants valued and did not value in some for both the experimental investigations and other areas of the instructional approach.

The intervention of the micro study of 2018 was modified for purposes of improving instruction in the next cycle of 2019. These changes were based on negative sentiments raised by participants in section 4.5.2. However, not many changes were made to the design of the intervention since some of the issues raised by participants were incorporated in the previous years and were being implemented each time a new intervention was in use. In this intervention, focus of change was on how to make the subject specific terminology used in tests more understandable to the participants, as this was one of the concerns raised by participants. An attempt was made to use alternative wording familiar to students but without losing the meaning of the intended message conveyed by the question. In certain circumstances when participants where writing questions, they would be asked before starting the test if they needed clarification with any of the questions, if need be, an explanation was given about what the question demanded of them.

Another area of concern on which modifications were based was issues raised to the effect that questions in the tests were not matching the information provided in the videos. Participants were informed that information disseminated through video material was deliberately made basic to for students to acquire these basic facts since it was needed to discuss content at a deeper level in class. They were constantly advised to read further and to pay attention to the discussions held in class especially when the instructor corrected misconceptions or was demonstrating how solve certain problems. Participants were constantly reminded that the information posted on videos could not be used to answer all questions on the test paper, but only few questions seeking to assess basic knowledge of basic facts. Further reasoning skills required to answer the question were to be developed by participants themselves with the assistance of the instructor during class discussions, and by reading with understanding of prescribed textbooks. Participants were constantly reminded of this at the beginning of each lesson and at the end of the lesson.

4.6 MICRO STUDY RESULTS OF 2019

4.6.1 Quantitative results of the modified SALG survey of 2019

4.6.1.1 Profile Data of Respondents

The study had 107 participants, with more males 74 (69.2%) than females 33 (30.8%) as revealed in Table 4.22.

Table 4. 22: Demographic Profile of the Respondents

Variable	Category	Frequency (N)	Percentage (%)
Gender	Female	33	30.8

	Male	74	69.2
	Total	107	100.0
Age	Under 18	1	.9
	18-19	6	5.6
	20-21	44	41.1
	22-24	38	35.5
	25 and above	18	16.8
	Total	107	100.0

The largest number (44) of respondents was in the age group 20-21 (41.1%). This was followed by the age group 22-24 with 38 (35.5%) of the respondents. The 25 and above age group had 18 (16.8%) and a few six (5.6%) of the participants being 18-19 years. There was also 1 (0.9%) student under the age of 18, unlike all other groups which had none.

4.6.1.2 Reliability Analysis

The questionnaire items analysed were 34. The reliability test found Cronbach's Alpha to have a value of $\alpha = .928$. Item statistics showed two items had low mean values compared to the rest of the other items. The two items were removed, and the Cronbach's Alpha fell slightly to .926. The value was still high for the data to be considered highly reliable with a total of 32 number of items analysed.

4.6.1.3 Suitability of Data for Factor Analysis

The data was tested for its feasibility for factor analysis by calculating the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett Test. The value of KMO was found to be .815 and the Bartlett's test of Sphericity had a Chi Square value of 1761.283 with significant value 0.000 as shown in Table 4.23.

Table 4. 23: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.815
Bartlett's Test of Sphericity	Approx. Chi-Square	1761.283
	df	496
	Sig.	.000

4.6.1.4 Factor Extraction

From a total of 32 variables analysed, 9 variables had Eigenvalues greater than 1, and a cumulative variance of 70.0%. Table 4.24 shows nine the factors identified as components in the first column.

Thus, according to the Eigenvalue criteria there are 9 major themes or underlying latent factors that can be identified from this data.

Table 4. 24: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.93	31.04	31.04	9.93	31.04	31.04	3.24	10.12	10.12
2	2.37	7.41	38.45	2.37	7.41	38.45	2.82	8.81	18.93
3	2.06	6.43	44.88	2.06	6.43	44.88	2.70	8.43	27.36
4	1.64	5.12	49.99	1.64	5.12	49.99	2.68	8.38	35.73
5	1.51	4.71	54.71	1.51	4.71	54.71	2.64	8.24	43.97
6	1.47	4.61	59.31	1.47	4.61	59.31	2.58	8.07	52.04
7	1.28	4.01	63.32	1.28	4.01	63.32	2.24	7.01	59.05
8	1.10	3.43	66.75	1.10	3.43	66.75	1.88	5.89	64.94
9	1.05	3.28	70.03	1.05	3.28	70.03	1.63	5.09	70.03
Extraction Method: Principal Component Analysis.									

4.6.1.5 The Scree Plot

The Scree Plot Figure 4.5 shows the Eigenvalues plotted against all the 32 variables in the questionnaire. It was used to verify the number of components extracted using the Eigenvalue criteria. The number of components extractable from the data set were the number of plots on the graph above the horizontal line drawn passing through the value of 1 on the Eigenvalue scale. Alternatively, a straight line drawn along the plotted curve starting from the last variable end until the point where the graph starts to curve upwards left 9 points. These points were considered as the number of principal components being sought.

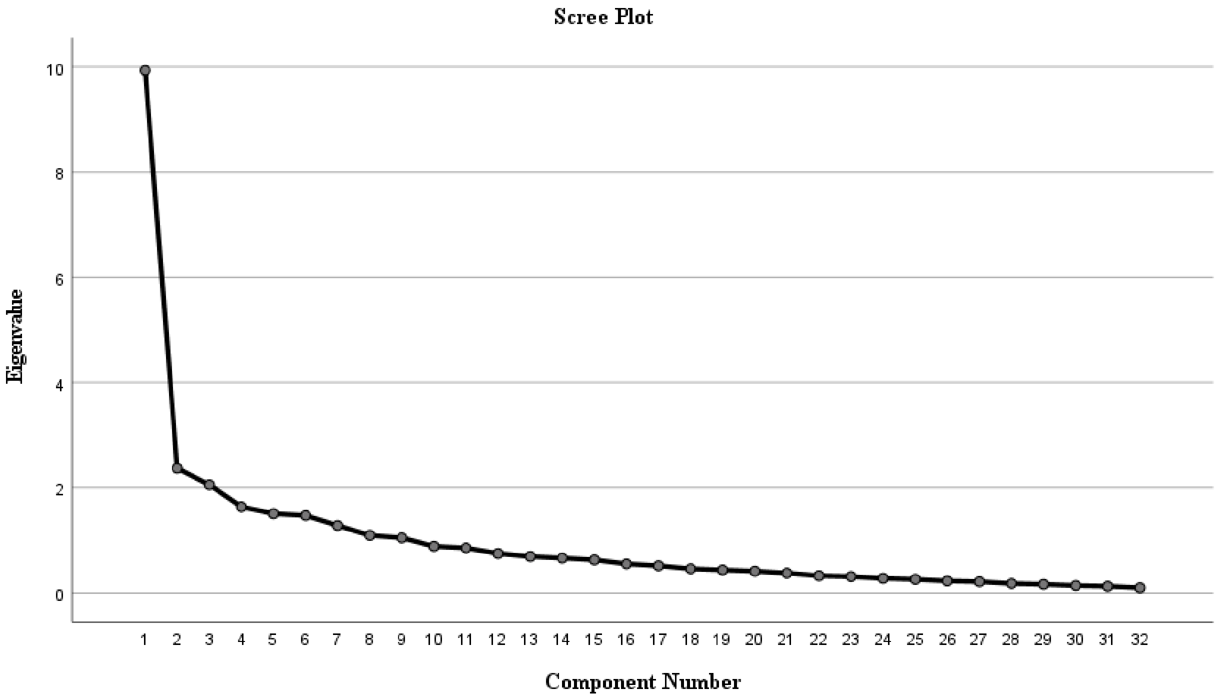


Figure 4. 5: Number of components extractable from the 32 variables

4.6.1.6 Naming the Factors

Factor rotation technique in SPSS was used to identify factors with variables that highly loaded onto them. Table 4.25 shows the factors, the cluster of variables with high loadings onto them, and their factor loadings. The cluster of variables for each factor was used to identify the underlying theme, which then helped to come up with a name for the factor. To come up with meaningful names, the top one or two variables with high loadings were used. Thus Factor 1 was associated with building of self-confidence of students, hence was named *building self-confidence to take charge of own learning*. Similarly, the other seven factors were named using the same technique. These factors were considered to influence student learning of geometric optics content.

Table 4. 25: Naming factors (derived from attributes and factor loadings) that influenced learning in participants of 2019

Factor	Factor attributes	Factor Loadings
Factor 1 Building interest and self-confidence to solve complex problems	Feeling at ease when working with complex problems in geometrical optics	.772
	Confidence that you understand geometrical optics	.745
	Your confidence to write the final examination	.683
	Enthusiasm for the subject of physics	.552
	Your interest to learn more of geometrical optics	.524
	Distinguishing between the roles played by the mirror, lens, and screen in image formation	.405
Developing of interest and confidence in solving complex problems in geometrical optics: mean = .613		

Factor 2 Knowledge and understanding of the nature of light	Distinguishing between ray and wave models of light	.716
	Distinguishing between mirror and diffuse reflections	.671
	Stating and using the key ideas outlined in the ray model of light	.620
Developing knowledge and understanding of the models of light using ray model assumptions: mean = .699		

Factor 3 Knowledge and application of ray tracing techniques with the mirror/lens equations	Using the ray tracing method to locate the image position of an object placed a specified distance from a mirror	.838
	Using the ray tracing method to locate the image position of an object placed a specified distance from a lens	.824
	Using the mirror equation and sign convention to determine the position, magnification and size of the image formed by a mirror	.615
	Using the lens equation and sign convention to determine the position, magnification and size of the image formed by a lens	.574
Developing skills in applying the sign convention and ray tracing techniques when solving complex and non-complex problems in geometrical optics: mean = .713		

Factor 4 Feedback for guiding instruction with video based activities	The feedback received from the instructor on questions posed during class discussions of content	.733
	The feedback on my work received after tests	.681
	Video presentations posted on blackboard by the instructor	.618
	The quiz written after watching each video presentation	.484
	Reading material recommended by the instructor	.473
Recommending watching video and reading materials, supported by meaningful feedback on graded and non-graded activities: mean = .598		

Factor 5 Participation in class discussions	Listening to discussions during class	.832
	Participating in discussions during class	.803
	Participating in group work during class	.574
Employing strategies that encourage collective and active participation during class discussions: mean = .736		

Factor 6 Level of demand of graded activities	The level of difficulty of the problems discussed in class	.629
	The level of difficulty of written tests	.588
	Applying the ray model, geometrical optics laws and principles in solving problems	.588
	Describing what happens to speed, frequency and wavelength when light goes from one medium into another.	.561
	Presentations by group representatives after discussion of problems in respective groups	.551
Assessing key geometrical optics ideas in line with cognitive demands addressed during class discussions: mean = .583		

Factor 7 Designing and implementation of investigation type activities	Pre-laboratory design activities	.846
	Laboratory practical activities	.837
Enhancing understanding of theory studied in class through designing and conducting laboratory activities: mean = .842		
Factor 8 Collaborative work	Your willingness to seek help from others when working on academic problems	.791
Encouraging collective effort when students are working on academic problems: mean = .791		

Factor 9 Organisation of learning activities	The order of priority used to discuss main ideas of the topic	.530
	In the way this module has been taught compared to the way your previous physics module was taught	.498
	Using Snell's law to predict the path of a light ray as it moves from one medium into another	.495
Organising learning activities according to sequencing of key ideas in geometrical optics: mean = .508		

In summary, the key factors that influenced student learning were those associated with:

1. Developing interest and confidence in solving complex problems in geometrical optics.
2. Developing knowledge and understanding of the models of light using ray model assumptions.
3. Developing skills in applying the sign convention and ray tracing techniques when solving complex and non-complex problems in geometrical optics.
4. Recommending watching video and reading materials, supported by meaningful feedback on graded and non-graded activities.
5. Employing strategies that encourage collective and active participation during class discussions.
6. Assessing key geometrical optics ideas in line with cognitive demands addressed during class discussions.
7. Enhancing understanding of theory studied in class through designing and conducting laboratory activities.
8. Encouraging collective effort when students are working on academic problems.
9. Organising learning activities according to sequencing of key ideas in geometrical optics.

4.6.2 Qualitative results from the SALG survey of 2019

The following lists are summaries of perceptions related to the strengths and weaknesses of the intervention.

Strengths associated with study of content

- The practical nature of the topic made it easier to understand its foundational knowledge such as the ray model and its assumptions, which are easily observable or experienced outside the classroom

Weaknesses associated with study of the content

- Though the topic was completed, not all content was covered, clearly explained, and understood. Such sections of the topic include operation of optical fibre, deduction and application of the laws that govern reflection of light.
- Not all sections of the topic were covered by a laboratory practical work to make it easier to understand theory studied in class since the practical work is an application of the theory.
- Though students gained a lot of knowledge of the topic of geometric optics, not enough time was available to go through the optic.

Weaknesses associated with the assessment

- The nature of questions in the assessment activities are way too hard for some students. The instructor set questions as though students were enrolled in a Bachelor of science (BSc) Physics programme.
- Students assumed the level of knowledge understanding demanded by the course syllabus was the same as that required at high school physics since they were going to be high school teachers. As such assessments beyond high school standards were considered too difficult for them.
- Because participants wrote three quizzes in MCQ format, each discussed during class time, their expectation was that the tests should also be in MCQ format so that the assessment would be familiar.
- Challenges faced by students in terms of the level of cognitive demand of the assessment activities was interpreted as non-alignment between how content was delivered in class and assessment itself.
- More time was needed between watching videos and the time the quiz was written.
- Some suggestions were that the quiz be written after the lesson, not before for it to consolidate what was discussed in class.
- Some views proposed reducing the level of difficulty of the questions in order to increase the pass rate.
- Examples given in class were expected to be replicated in tests and examinations, and this was interpreted by some participants as assessment in accordance to what the instructor teaches.
- Lecture method was still preferable method of teaching to some participants, with an assignment being suggested as a better method of assessment to them. Suggestions were to cancel the quiz and to replace them with assignments.

Strengths associated with feedback

- The feedback given in class immediately after the quiz was written, helped rectify misunderstandings carried over from the study of the video materials, as well as providing the foundational knowledge that was need for a deeper understanding of the new content that was planned for that lesson.

Weaknesses associated with the feedback

- Some of the narratives provided suggested that feedback given was not proper, because it lacked substantial evidence or examples to support what the instructor proposed as the correct responses. The feedback was therefore not adequate, not well-structured and did not integrate concepts hence confused students.
- The facilitator did not provide students a written memorandum after giving oral feedback
- The instructor did not return student scripts to their owners and this deprived student of self-assessment. As such the oral feedback through revision of tests was ineffective and not constructive.

Strengths associated with video materials

- The videos helped students to understand both the basic concepts and the complex ones.

Weaknesses associated with video materials

- The lecturer depended more on video materials as the main source of learning prior to in-class activities, rather than other materials which are not videos.
- The instructor did not make it a point to explain in class the content that was not fully explained in the video materials disseminated.
- Some of the video materials provided focused more on application of concepts than providing the basic facts necessary to be able to understand and apply the concepts applied.
- The instructor did not provide more of the video materials to accommodate the various parts of the topics under discussion.
- The instructor, at times delayed posting the video materials leaving students with very little time to view them before the quiz was written.
- To improve the understanding of concepts taught, some of the views suggested the video materials could be brought into the classroom so that the instructor could explain further the content on the videos, and thereafter go into detail after the video has been watched in class.

- The instructor was not using video materials to set items for the tests given, thus videos were not helpful.

Strengths associated with class discussions

- Both video strategy and class discussion strategy contributed a lot to the understanding of geometrical optics content.
- Students who made use of video materials were of the view that one understands a lot if they study before the class
- Discussions during class do clarify many misconceptions
- More group work helps students to learn from one another
- Interactions where students engage with the instructor are really helpful a lot.
- Class discussion after watching the videos help students engage productively with others
- Students have more to benefit when engaged in group activities than in individual activities.

Weaknesses associated with class discussions

- Students were still entrenched in the idea of a lecture in their view that class activities should be about what we have learned not what we are going to learn.
- There were students whose view were that presentations consume time, without realising that more calculations through these representations might help them to understanding the content deeply
- The instructor should work to establish teacher to student interaction and students to student interaction to accommodate students' different learning styles.
- For classes that are of a large size, at times the instructor may not realise that not everybody was paying attention to the activity that might be taking place.
- The instructor should not assume that when students who are academically gifted present well their work, then the rest of the student body understands as well.
- There is need for students to ask questions requiring greater details to encourage the instructor to provide responses that have detail
- Questions of different degrees of difficulty were distributed to different groups, this causes some groups to have an advantage over others if the activity ends up being graded.
- Provide more examples where the use of diagrams in explaining answers or mathematical calculations may be seen to be helpful.

- Provide more opportunities for students to solve problems in class
- The instructor should use both explanations and practical demonstrations in teaching physics concepts.
- The instructor should use various active learning instructional strategies in class rather than heavily relying on one strategy
- Student groups have their limitations, which the instructor should be aware of in order to correctly manage the dynamics of each group.
- Students do not yet realise that video materials are there to present basic concepts where details are dealt with during class time

Weaknesses associated with guidance

No opinions about strengths associated with this item were raised but the following negative sentiments:

- The instructor did not make students become aware about what they were dealing with.
- The content was not adequately explained before assessment
- The instructor was not specific when it came to the objectives of the lesson
- The instructor did not give orientation on what to do before watching the video materials or write a quiz. The information helps students to actively engage with the learning material provided.
- The instructor should be accessible for assistance at any time rather than directing students to read the prescribed materials.

Strengths associated with the instructional approach in general

- The instructor engaged students in the learning physics at high level of thinking because he provided basic information and he set difficult test
- Everything involved in the process of teaching and learning was well presented,
- The way the instructor was teaching was enjoyable and really helped a lot of students. The method was good, because it allowed students to have an overview about what was going to happen in the class.
- The approach paved way for conceptual understanding of the topic geometrical optics and it's all thanks to teaching methods employed by the module instructor
- The teaching approach inspires to want to learn more and become a physics teacher.

Weaknesses associated with the instructional approach in general

- The instructor was should have conducted actual lectures than using this new approach for students to understand a lot, especially before giving us assessments.
- The instructor should go deeper where difficult issues must be used to force students to reason.
- The instructor should improve the method of instructing the lessons by explaining the content in detail, because videos do not have much of the specific information which students are expected to provide.
- The teaching of the module should take more hours than normal because the topic is large, and the depth of knowledge students are expected to master cannot be achieved within the time allocated.

Strengths associated with learning materials other than video material

- The instructor always made sure most of the study material students required was prepared and given on time. he kept his promises about putting notes and study material on blackboard which encourages students to study. It is recommended that he keeps that strategy up.

Weaknesses associated with learning materials other than video material

- The physics language of some textbooks was difficult for some students to understand. When it was time for the students to be assessed, the reading material and the assessment seemed to be addressing two different issues, because students failed to understand what the material was saying and what the test would be asking seemed to be something else not found in the reading material, and the instructor appears as he misguided the students.
- Sometimes materials ere uploaded when there was not enough time to go through them before an assessment activity.
- There is need for a variety of study material to be made available to students so students can be exposed to different explanations of the same phenomena for a better understanding of it.
- The instructor explained the concepts better than what was in the reading materials or was understood better than the way the reading materials did. This caused students to be less confident with reading materials.

Strengths associated with the Lecturer

- The lecturer demanded students to read or research more about the physics content, and in so doing removed the laziness in some of the students when it comes to learning.

Weaknesses associated with the Lecturer

- Though the instructor encouraged students to engage in further reading, some viewed at the lecturer as encouraging students to do research and studying without guidance, because the lecturer was considered to be disregarding a lot of pressure from other modules which students needed time to attend to.
- The lecturer referred students to video materials without introducing the topic giving background information.

Weaknesses associated with post class activities

No positive sentiments except the following negative sentiments that were brought up.

- The activities that took place in class were not helpful to some students because many things were always said, but when the students studied on their own, it helped them a lot.
- Some students felt the challenging such that they needed extra classes before examinations began.
- There was no group discussion platform created for students to discuss academic issues after the class.

Table 4.26 is a summary of issues raised by participants in the open-ended questions of the survey instrument. Each participant had something to say, either as a positive or negative sentiment, and a collection of all the issues was made and grouped into themes listed in Table 4.26. Under these themes, the issues were summarised in main ideas either as strengths associated with a particular theme or weaknesses associated with a particular theme as indicated in the previous section. On further inspection of Table 4.26, it can be observed that there were themes that were mentioned

Table 4. 26: How strongly participants felt about each educational aspect identified thematically

Code	Theme	Count showing how many times a theme was mentioned	Count expressed as a (%)
1	Content	13	8
2	Assessment	51	32
3	Videos	13	8
4	Feedback	9	6
5	Class discussion	29	18
6	Guidance	5	3
7	Instruction	23	14
8	Other learning material	8	5
9	Lecturer	6	4
10	Post class activity	3	2
TOTAL		160	100

more than others. The third and fourth columns of the table shows how many times the themes were mentioned, expressed both as a number and as a percentage, respectively. Ranking the themes according to how many times it was mentioned, were issues associated with assessment (32%) at the top, followed by those issues related to class discussions (18%), and on third of the list were issues related to the instructional approach in general (14%). At the bottom of the list were issues related to post or after class activities (2%). The ranking shows where participants were greatly concerned, and what was at the least of their concern.

No interviews were conducted with the group of 2019. The researcher considered the information provided in the interviews with previous groups to be almost similar, with no new information likely to emerge from further interviews. Thus, data that was collected through interviews each year was considered to have reached saturation, hence it was unnecessary to conduct further interviews.

It was also noted that, though changes were done each year to modify the design of the intervention, still issues of the same nature were constantly raised by participants in their responses to the open-ended questions. Such issues include:

- not being able to cover all of the content
- not enough time was made available to cover the content
- questions in assessment activities being too difficult for the participants
- participants still preferring the lecture method over the FCA
- not being satisfied with the feedback given,

These are among some of the items that kept on being repeatedly pointed out under weaknesses of the study. Changes that were made to address these issues, among other modifications to the instruction, included:

- the content to be covered was specified through the course outlines, anything outside that student were informed was not to be part of assessment.
- more videos covering different aspects of content were provided to participants, as well as worksheets, allowing students to experience how the content could be applied in solving problems of different nature.
- students were exposed to problems of the same cognitive demand during class discussions, as those they were to experience during tests and examinations.

- student were allowed to view their scripts at any time they wanted provided the instructor was available and not committed with other duties related to his work.

However, several reasons may be pointed out to why these issues were repeatedly highlighted each year, though modifications were done. There is need to understand the context in which all groups that were subjected to this study operated. These students were preservice teachers under training. Their time to engage with the subject material was very limited, in the sense that part of their time was spent outside the university engaged in teaching practice sessions. During that time, they had no contact with their instructor, but had to engage with the material of study. These teaching practice sessions would take six weeks, but still students were expected to engage with their study material. Thus, in this case video material and worksheets were posted online, expecting students to work on their own. By the time they return to the university from teaching practice sessions, there was no time to revisit some of the material done by students alone while they were away from the university, except to move on to cover the content remaining before end of semester exams started. This context had a negative impact to middle and low performers, from which most of the comments provided originated.

Taking into consideration also that the majority of the participants had a rural background, without a strong physics background at high school level, including English as a medium of instruction, was not their first language and were struggling with it, these issues affected each group and their learning, hence the recurrence of the same issues being mentioned though attempts were made to modify the instructional approach.

4.7 FINDINGS ON EFFECTIVENESS OF THE INTERVENTION

In order to determine the extent to which the FCA-based intervention was effective in inducing change in conceptual understanding of geometrical optics in student participants, the LOCE instrument was given to students before and after the instruction of the course, and Hake's normalised gain calculated. The raw data (in percentage) collected for the three microstudies is shown in Tables (4.27), (4.28) and (4.29).

Table: 4.27 Pre-and Post-test raw scores for 2017 microstudy

Std. ID	Pre	Pos	Std. ID	Pre	Pos	Std. ID	Pre	Pos	Std. ID	Pre	Pos
1	33	35	**34**	50	48	**66**	33	35	**98**	20	38

2	33	60	**35**	38	50	**67**	28	58	**99**	20	33
3	30	40	**36**	30	40	**68**	28	50	**100**	40	55
4	33	48	**37**	38	35	**69**	40	38	**101**	38	40
5	23	28	**38**	40	50	**70**	55	60	**102**	18	28
6	28	33	**39**	48	53	**71**	33	30	**103**	25	43
7	38	55	**40**	30	40	**72**	30	50	**104**	20	38
8	20	38	**41**	33	40	**73**	18	60	**105**	38	55
9	33	55	**42**	63	65	**74**	25	48	**106**	20	48
10	43	65	**43**	35	53	**75**	25	38	**107**	23	33
11	40	40	**44**	45	55	**76**	33	43	**108**	40	48
12	40	58	**45**	25	20	**77**	33	65	**109**	15	28
13	20	33	**46**	33	33	**78**	45	48	**110**	33	45
14	23	40	**47**	33	40	**79**	18	28	**111**	25	35
15	30	43	**48**	15	33	**80**	35	50	**112**	28	30
16	20	38	**49**	40	48	**81**	50	53	**113**	18	23
17	48	43	**50**	30	43	**82**	23	23	**114**	33	45
18	30	33	**51**	15	15	**83**	33	50	**115**	33	33
19	53	58	**52**	25	20	**84**	33	60	**116**	25	33
20	28	40	**53**	30	30	**85**	35	55	**117**	30	45
21	58	58	**54**	38	55	**86**	18	43	**118**	25	43
22	43	50	**55**	43	50	**87**	18	45	**119**	25	45
23	33	28	**56**	20	55	**88**	45	60	**120**	38	55
24	23	40	**57**	35	40	**89**	38	33	**121**	20	40
25	30	40	**58**	30	40	**90**	48	48	**122**	50	58
26	43	63	**59**	38	35	**91**	40	53	**123**	43	40
27	43	45	**60**	35	50	**92**	38	35	**124**	43	53
28	28	48	**61**	33	43	**93**	30	50	**125**	18	30
29	40	58	**62**	38	50	**94**	38	45	**126**	33	43
30	43	40	**63**	35	58	**95**	35	68	**127**	38	35
31	48	43	**64**	40	40	**96**	30	38	**128**	25	33
32	38	63	**65**	38	38	**97**	30	30	**129**	53	60
33	30	53									

Table: 4.28 Pre- and Post-test raw scores for 2018 microstudy

Std. ID	Pre	Pos	Std. ID	Pre	Pos	Std. ID	Pre	Pos	Std. ID	Pre	Pos
1	28	33	**35**	23	43	**68**	38	53	**101**	40	55
2	10	43	**36**	23	38	**69**	30	38	**102**	25	70
3	35	50	**37**	25	48	**70**	25	45	**103**	23	65
4	25	55	**38**	28	48	**71**	38	43	**104**	23	53
5	33	43	**39**	25	30	**72**	25	28	**105**	10	33
6	30	33	**40**	43	45	**73**	35	40	**106**	33	48
7	25	48	**41**	28	43	**74**	23	45	**107**	33	53
8	25	43	**42**	13	18	**75**	20	45	**108**	35	38

9	35	45	**43**	30	35	**76**	20	30	**109**	23	43
10	30	40	**44**	30	65	**77**	25	28	**110**	40	78
11	43	55	**45**	25	48	**78**	35	40	**111**	35	43
12	50	70	**46**	38	45	**79**	33	38	**112**	25	58
13	20	33	**47**	28	43	**80**	43	40	**113**	30	48
14	28	33	**48**	25	33	**81**	25	25	**114**	38	65
15	25	65	**49**	33	50	**82**	30	50	**115**	40	43
16	30	43	**50**	33	48	**83**	23	30	**116**	28	45
17	28	53	**51**	28	55	**84**	28	35	**117**	30	55
18	28	55	**52**	33	43	**85**	30	35	**118**	30	58
19	20	28	**53**	28	30	**86**	25	60	**119**	20	60
20	13	45	**54**	20	33	**87**	28	55	**120**	25	48
21	25	28	**55**	30	43	**88**	20	53	**121**	28	35
22	23	35	**56**	30	53	**89**	33	35	**122**	20	48
23	25	38	**57**	18	20	**90**	20	48	**123**	28	33
24	23	43	**58**	20	40	**91**	20	35	**124**	28	35
25	18	33	**59**	28	38	**92**	30	43	**125**	30	48
26	20	48	**60**	18	28	**93**	33	45	**126**	20	50
27	33	33	**61**	23	30	**94**	30	45	**127**	23	28
28	38	43	**62**	23	55	**95**	28	53	**128**	20	45
29	30	58	**63**	28	40	**96**	30	43	**129**	30	53
30	28	45	**64**	20	30	**97**	28	55	**130**	25	30
31	28	50	**65**	28	40	**98**	40	58	**131**	23	55
32	30	60	**66**	20	33	**99**	20	53	**132**	15	33
33	13	45	**67**	20	35	**100**	28	53	**133**	30	38
34	33	35									

Table: 4.29 Pre and Post-test raw scores for 2019 microstudy

Std. ID	Pre	Pos	Std. ID	Pre	Pos	Std. ID	Pre	Pos	Std. ID	Pre	Pos
1	30	30	**27**	23	60	**53**	33	55	**78**	25	50
2	25	33	**28**	20	25	**54**	33	50	**79**	15	35
3	30	33	**29**	30	53	**55**	30	50	**80**	23	45
4	20	38	**30**	28	40	**56**	50	73	**81**	25	40
5	35	35	**31**	18	43	**57**	33	30	**82**	40	63
6	23	28	**32**	25	30	**58**	23	28	**83**	18	38
7	33	40	**33**	40	60	**59**	23	45	**84**	33	43
8	20	43	**34**	13	53	**60**	43	55	**85**	15	43
9	45	58	**35**	25	38	**61**	35	58	**86**	35	48
10	23	33	**36**	23	45	**62**	30	45	**87**	18	20
11	35	53	**37**	28	45	**63**	23	20	**88**	8	50
12	20	38	**38**	35	55	**64**	30	48	**89**	25	53
13	23	20	**39**	20	68	**65**	18	50	**90**	23	33
14	50	60	**40**	25	58	**66**	50	45	**91**	20	58
15	25	35	**41**	25	38	**67**	25	40	**92**	25	48

16	38	63	**42**	35	45	**68**	33	48	**93**	5	25
17	33	35	**43**	33	45	**69**	20	48	**94**	33	35
18	25	33	**44**	13	30	**70**	28	40	**95**	35	55
19	38	60	**45**	45	45	**71**	40	53	**96**	23	60
20	20	53	**46**	23	28	**72**	28	50	**97**	38	45
21	35	48	**47**	20	25	**73**	10	35	**98**	15	33
22	23	48	**48**	28	48	**74**	33	63	**99**	33	40
23	23	45	**49**	33	48	**75**	43	48	**100**	38	45
24	13	38	**50**	35	40	**76**	20	33	**101**	23	40
25	30	38	**51**	20	25	**77**	23	28	**102**	30	35
26	20	20	**52**	15	38						

According to Hake (1998), students' learning gain in conceptual understanding of a particular subject matter content can be determined using the following expression:

Normalised Gain (G) = $\frac{<post> - <pre>}{100\% - <pre>}$, where the pre and post scores are expressed as a percentage. In this study, calculation of the normalised gain was conducted using SPSS version 26, and the values for G for each microstudy is shown in Table (4.30).

Table (4.30) values of normalised gain for the microstudies

	2017 (N=129)	2018 (N=133)	2019 (N=102)
Normalised Gain	0.16	0.23	0.21

According to the results in Table 4.27, the values show that the FCA based intervention induced an increased change of 0.16 in conceptual understanding of geometrical optics, in the class of 2017, then a change of 0.23 in the class of 2018, and 0.21 in the class of 2019. Hake (1998) proposed three categories of G as a way of determining the extent of the effectiveness of an intervention, which are: G $>$ 0.7 for high achievement level, 0.3 $\leq$ G $\leq$ 0.7 for medium achievement level, and G $<$ 0.3 for low achievement level. Thus, the G factor takes values between 0 and 1, where 0 implies that no learning took place, while 1 implies maximum possible learning that took place. In this study, all values of the G factor lie below 0.3 but above 0, implying there was learning that took place that led to an improvement in conceptual understanding of geometrical optics. However, the effectiveness of the intervention was at lower level, which would be interesting to examine on why this is so when interactive engagement was employed throughout the instructional process.

In addition to the evaluation conducted on the effectiveness of the FCA-based intervention using the normalised gain method, a further analysis was also conducted using the ANCOVA method, in which the effects of students' prior knowledge status of geometrical optics were controlled as the covariate. The LOCE instrument was analysed using One Way ANCOVA in SPSS version 26 and the results are shown in Table 4.31 and Table 4.32.

Table 4. 31: Achievement by instruction Type and Prior Performance

Type of Instruction	Achievement			
	Unadjusted Post Scores Mean	Adjusted Post Scores Mean	SD	N
2017	15.73	14.93	4.94	129
2018	17.23	17.67	4.62	133
2019	16.92	17.36	4.76	102
Source	SS	df	MS	F
Test One	510.611	1	510.61	23.85* (Sig. 0.00)
Group	457.347	2	228.67	10.68* (Sig. 0.00)
Error	7708.04	360	21.41	

Note: R^2 = 0.080, Adj. R^2 = 0.073, adjustments based on Pre-Score Mean = 12.46, Homogeneity of variances among groups tested and not significant: F = 0.54, $p > 0.05$.

The results in Table 4.31 show that there were instructional differences which were statistically significant in terms of participant achievement: F (2, 360) = 10.68, $p < 0.05$), and that the achievement itself was positively impacted by prior student knowledge (Test One: F (1, 360) = 23.85, $p < 0.05$). In terms of visual mean scores in Table 4.31, the 2018 group showed best performance among the three groups in both means 17.23 and 17.67, prior to and after adjustment respectively. The second group to perform best was the 2019 group, with mean scores prior to and after adjustment of 16.92 and 17.36 respectively. The least performance was in the group of 2017 with 15.73 and 14.93 mean scores before and after adjustment respectively.

Table 4.31 served as evidence to confirm that FCA instructional strategy, as an instructional intervention used in the study, had a significant effect on student achievement / performance, but did not tell at which group level the instructional intervention produced the significant effect.

Table 4.32 shows the group comparisons which were used to identify the specific group(s) in which the improved versions of FCA instructional strategy led to the differences in students' learning. When all groups were compared pairwise in terms of mean differences in achievement (determined using post-score means), statistically significant differences in achievement were noted between groups of 2017 and 2018 (2.74, $p < 0.05$) as well as those of 2017 and 2019 (2.42, $p < 0.05$). Though there were some differences in performance between groups of 2018 and 2019, the difference was not statistically significant (0.32, p = 1.00). The confidence Intervals (CI) show that in all three cases, there was only a 5% chance that the mean differences could lie outside the CI of 95% of each the respective means.

Table 4. 327: Comparisons of mean differences in achievement by group instruction type

Comparison	Mean Difference	Standard Error	Bonferroni Adjusted 95% CI
2017 vs 2018	-2.74^{*} ($p < 0.05$)	0.63	-4.24, -1.24
2017 vs 2019	-2.42^{*} ($p < 0.05$)	0.66	-4.02, -0.83
2018 vs 2019	0.32 ($p > 0.05$)	0.61	-1.15, 1.78

Note: Comparisons upon ANCOVA adjusted means controlling for prior performance mean (pre scores) = 12.46. $P^{*} < 0.05$ where p-values are adjusted using the Bonferroni method.

4.8. SUMMARY OF CHAPTER 4

The main goal of this chapter was to present the analysis and findings of the data collected to answer the research questions of the study. The presentation of the data was organised in six sections, where the first section was about the results of the pilot study conducted in 2015, while four other sections focused on results of the micro studies of 2016, 2017, 2018, and 2019. The last section provided results of the effectiveness of the interventions employed.

For each micro study conducted, the results were organised in three main categories – quantitative results of the survey (SALG) instrument, qualitative results of the survey (SALG) instrument, and the interview results. For the quantitative results of the survey instrument, the findings of each micro study were a set of factors that were found to influence learning in student participants. A summary of all the findings from the pilot study of 2015 to the pilot study of 2019 are shown in

Table 4.33. Summary of factors that influenced learning for each micro study

The pilot study of 2015
Factors that influenced learning were associated with: 1. Identifying and exploring key ideas in geometrical optics used to develop logical arguments, interrelating them with other physics ideas. 2. Employing strategies that promote active participation during class discussions. 3. Providing feedback on graded activities motivating students to be prepared to make oral presentations in class and critically read materials after class. 4. Encouraging students to use evidence-based reasoned arguments. 5. Promoting the use of formative graded activities that are in line with key ideas taught 6. Incorporating real-life implications of theory studied in class. 7. Encouraging reasoning based on key ideas studied in class beyond the classroom. 8. Providing video-based activities on time in support of class discussion activities. 9. Considering time, space, and mental stretch when planning for content delivery and grading activities to allow a systematic reasoned approach to solving problems.

10. Allowing students to interrelate key geometrical optics ideas to other scientific ideas.
11. Developing interest in the subject allowing students to take charge of their own learning.
12. Showing students how different activities they are involved in are interrelated.
13. Developing confidence in students allowing them to take charge of their own learning.

Micro study of 2016

Factors that influenced learning were associated with:

1. Promoting strategies that motivate students to take charge of their own learning in order to solve complex problems in geometric optics.
2. Employing strategies that encourage active participation in class discussions.
3. Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics.
4. Providing feedback and guidance on all formative activities and relevant reading materials that meet the required levels of demand of problems discussed in class and in written tests.
5. Encouraging students to watch video materials by compelling them to answer a formative quiz only after watching the video material.
6. Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics.
7. Identifying and applying knowledge, concepts, skills, and key ideas needed for solving complex problems in geometrical optics.
8. Identifying and applying knowledge, concepts, and skills needed for solving complex problems in geometrical optics.

Micro study of 2017

Factors that influenced student learning were associated with:

1. Developing students' interest and confidence for solving complex problems by allowing them to take charge of their own learning.
2. Employing strategies that encourage active participation in class discussions when solving complex problems in geometrical optics.
3. Developing key geometrical optics ideas in students through reading of recommended materials and conducting practical investigations.
4. Developing student abilities for solving complex problems in geometrical optics through the use of the sign convention and ray tracing techniques.
5. Developing and applying knowledge of concepts, laws, and principles of geometrical optics for solving complex problems in geometrical optics.
6. Providing feedback to all formative graded and non-graded activities associated with class discussions.
7. Encouraging students to watch video materials by compelling them to answer a formative quiz only after watching the video material.
8. Encouraging collective effort when students are working on academic problems.

Micro study of 2018

Factors that influenced learning were associated with:

1. Employing strategies that encourage collective active participation in class discussions about key geometrical optics ideas when solving complex problems
2. Developing knowledge and abilities of ray tracing techniques based on ray model of light
3. Developing students' interest and confidence for solving complex problems by allowing them to take charge of their own learning
4. Developing and applying knowledge of concepts, laws, and principles of geometrical optics for solving complex problems based on students' feedback from questions posed during class discussions
5. Encouraging students to watch quiz-motivated video materials and reading of instructor recommended materials for solving complex problems in geometrical optics
6. Developing knowledge and skills needed for solving complex problems using key geometrical optics ideas

Micro study of 2019

Factors that influenced learning were associated with:

1. Encouraging students to take charge of their own learning by developing interest and confidence in solving complex problems using key ideas in geometrical optics.
2. Developing knowledge and understanding of the models of light using ray model assumptions.
3. Developing skills in applying the sign convention and ray tracing techniques when solving complex and non-complex problems in geometrical optics.
4. Recommending watching video and reading materials, supported by meaningful feedback on graded and non-graded activities.
5. Employing strategies that encourage collective and active participation during class discussions.
6. Assessing key geometrical optics ideas in line with cognitive demands addressed during class discussions.
7. Enhancing understanding of theory studied in class through designing and conducting laboratory activities.
8. Encouraging collective effort when students are working on academic problems.
9. Organising learning activities according to sequencing of key ideas in geometrical optics.

In summary, after examination of all factors listed in Table 4.33, most of the factors or ideas are repeated or commonly found in two or more of the other micro study findings. Ideas that repeatedly appeared were synthesised to form one opinion. The result of this synthesis was a set of ten key factors considered to have influenced learning in students during the duration of the study:

1. Identify key ideas in geometrical optics to enable students to understand and transfer their understanding to other learning situations during and after the course.
2. Planning should consider time, space, and cognitive demand students will experience during and after class meetings.
3. Prepare students for face-to-face class activities, by requiring them to answer a formative quiz, based on video material, provided on time, prior to class meetings.
4. Enhance understanding of key ideas in geometrical optics through a variety of classroom activities, incorporating real-life implications of theory studied in class, supported by designing and conducting relevant laboratory activities.
5. Employ strategies requiring peer collaboration and active participation, when solving complex problems in geometrical optics, during and after class meetings.
6. Ensure that students use evidence-based reasoned logical arguments, based on key ideas in geometrical optics, when solving complex problems.
7. Allow students to take charge of their own learning by developing interest and confidence for solving complex problems.
8. Provide assessment activities that are in line with key ideas of the topic under study, to monitor student progress.
9. Critically and timely, provide students with appropriate feedback on all graded activities, so they can read materials with understanding during and after class meetings.
10. Show how different activities students are involved in depend on each other and are organised according to key ideas in geometrical optics.

These findings form the components of the FCA-based intervention that commonly influenced learning in all groups of the participants involved in this study.

The qualitative part of the SALG survey instrument yielded ten themes representing issues that influenced learning in student participants. A summary of these themes against the number of times each theme was repeatedly mentioned is provided in Table 4.34, for each of the micro studies conducted. The themes were earlier on explained under each of the sections dealing with each micro study. In this section, Table 4.34 serves only to provide a grand view of all the themes when all groups studied are placed together to allow examination of how each theme fared across groups.

Table 4.284: Summary of themes and the number of times it was mentioned (count) per group

Code	Themes	2016 (n = 75)		2017 (n = 123)		2018 (n = 146)		2019 (n = 107)	
		Count	%	Count	%	Count	%	Count	%
1	Content	10	11	19	11	27	12	13	8
2	Assessment	12	13	21	12	67	30	51	32
3	Videos	29	30	39	22	22	10	13	8
4	Feedback	10	11	14	8	13	6	9	6
5	Class discussion	17	18	9	5	36	16	29	18
6	Guidance	3	3	5	3	7	3	5	3
7	Instruction	10	10	35	20	23	10	23	14
8	Other learning materials	0	0	5	3	10	4	8	5
9	Lecturer	4	4	19	11	14	6	6	4
10	After class activities	0	0	9	5	7	3	3	2
TOTAL COUNTS		95	100	175	100	226	100	160	100

The number of times each theme was mentioned reflects how strongly students of a particular group felt about this aspect of learning, when the intervention was being tested (see section 4.3.2; 4.4.2; 4.5.2 and 4.6.2 for details of participant views). From these results, the first two years of the study (2016 and 2017), videos, class discussions and instruction (managing the instructional process) had the most influence on student learning, in one way or another. In the last two years (2018 and 2019) assessment, class discussions and instruction, had the most influence. What can be deduced from these results is that there were four key factors - video material, class discussions, instruction and assessment, which in one way or another, had a strong influence in student learning since students felt very strongly about them. When examined across groups, content was mentioned nearly the same number of times in the first three groups, only decreasing in the last group. For assessment the trend was increasing with the highest (32%) percentage being in the group of 2019. The trend on videos was decreasing on how frequently it was mentioned comparing groups. The rest of the other themes show no specific trends, most of them with small values of how frequently they were mentioned small.

During the duration of the study, eleven student participants were selected and interviewed. The selection was based on whether students were high, middle, or low achievers. There were no interviews conducted for the pilot group of 2015. However, four participants were interviewed in 2016, four in 2017, and three in 2018. No interviews were conducted in 2019 as interview results from previous years seemed to show that the same ideas were being repeatedly mentioned. A narrative analysis of the interview data was conducted for each question listed on the interview protocol in order to get a deeper insight of student understanding of the educational issues pursued in the questions posed to the participants. Each of the ten questions on the interview protocol was converted into a discussion theme. Thus the ten themes corresponding to each question were: content level difficulty (1), ability to solve physics challenging problem (2), the hybrid nature of the course (3), post class assistance (4), class discussions (5), teaching-learning materials (6), examination preparation (7), limitations of the instructional materials (8), sequencing of study units (9) and laboratory experience (10). The interview findings for each student cohort of 2016, 2017, and 2018, were discussed under these themes. The major issues raised by participants after summarising all findings from the three groups are:

1. Workload related time constraints
2. Video benefits and challenges
3. Employing interactive engagement strategies
4. Using feedback for learning
5. Challenges related to poorly resourced large class size
6. Incorrect perceptions about the rationale behind the use of video content
7. Laboratory experience as learning by doing
8. Students post-class learning communities
9. Challenges with terminology used in physics language

The intervention used in the study was also tested on whether it had any effect at all on students' performance, but after it had undergone some modifications before use with each particular group. The findings showed the intervention was statistically more effective on two of the groups. In other words the results of the ANCOVA show how the effectiveness of the intervention changed with the introduction of changes in the intervention.

CHAPTER 5

DISCUSSION, CONCLUSION & RECOMMENDATIONS

5.1 INTRODUCTION

The purpose of this study was to design and implement an intervention for teaching geometrical optics based on flipped classroom approach framework.

To achieve this purpose, the study was guided by the following research questions:

1. What components of a flipped classroom are appropriate for designing a geometrical optics course in physics?
2. How do components of a flipped classroom approach inform the design of a geometrical optics course in physics?
3. What is the effect of the Flipped Classroom Approach (FCA) intervention on students' performance in geometrical optics in physics?

This chapter discusses the major findings that were presented in Chapter 4 (section 4.8) in relation to instructional design, based on the flipped classroom approach framework. It is organised into five sections, in which the first section is the introduction of the chapter, where the purpose and research questions of the study are re-emphasised. The second section focuses on components of flipped classroom approach (see section 5.2). The third section discusses how these components may be used to inform the design of geometrical optics course (see section 5.3). The fourth section discusses the effectiveness of the intervention on students' performance (see section 5.4). The fifth section discusses the implications of these findings (see section 5.5). The sixth section provides the limitations of the study (see section 5.6). Section seven provides the conclusion and recommendations of the study (see section 5.7), which is a summary of the findings of the study and recommendations for future studies.

5.2 COMPONENTS OF THE FLIPPED CLASSROOM APPROACH

1.2.1 Discussion of the components

The first research question sought to find out about the components of the FCA-based intervention by asking: *What components of a flipped classroom are appropriate for designing a geometrical optics course in physics?* The study found ten components associated with the designing of an instructional intervention for a geometrical optics course, based on the flipped classroom approach framework. These components are listed in the following paragraph according to order of priority:

1. Identify key ideas in geometrical optics to enable students to understand and transfer their understanding to other learning situations during and after the course.
2. Planning should consider time, space, and cognitive demand students will experience during and after class meetings.
3. Prepare students for face-to-face class activities, by requiring them to answer a formative quiz, based on video material, provided on time, prior to class meetings.
4. Enhance understanding of key ideas in geometrical optics through a variety of classroom activities, incorporating real-life implications of theory studied in class, supported by designing and conducting relevant laboratory activities.
5. Employ strategies requiring peer collaboration and active participation, when solving complex problems in geometrical optics, during and after class meetings.
6. Ensure that students use evidence-based reasoned logical arguments, based on key ideas in geometrical optics, when solving complex problems.
7. Allow students to take charge of their own learning by developing interest and confidence for solving complex problems.
8. Provide assessment activities that are in line with key ideas of the topic under study, to monitor student progress.
9. Critically and timely, provide students with appropriate feedback on all graded activities, so they can read materials with understanding during and after class meetings.
10. Show how different activities students are involved in depend on each other and are organised according to key ideas in geometrical optics.

This study was about determining the components of a flipped classroom. The methodology used the principles from literature to design an initial intervention, upon which further micro studies were conducted. In this first section, the discussion centers on how the eight components, as findings of the study that address the first research question, support the results found in other studies in the literature that was discussed in chapter 2, (see section 2.4.4) about FCA.

In chapter 2 (section 2.4.4), Martínez, Lombaerts & Celaya, (2017) used Fink's model within the conceptual framework of FCA to come up with an FCA instructional model for delivering a course. They provided their own observations about how students performed on the tasks they were asked to perform, how students adopted to the new instructional approach and students' recommendations, as findings of their study. Their study was not set to obtain principles for designing FCA but to use the approach and see whether it was acceptable to students. Among the recommendations provided by the students were *(a) an increase in collaborative work*, *(b) giving students greater opportunity to engage in the learning process in the classroom or by social networks*, and *(c) promotion of activities that have impact beyond the course itself*.

The first finding (a) from Martinez et al. (2017) showed that the results of their survey indicated the need to increase collaborative work. In this study, component 6 supports their findings. It talks about the need for collective effort on the part of students, when they are working on a task, whether it be in class or out of the class.

The second finding (b) of these researchers was about a greater opportunity to be provided to students to engage in the learning process in the classroom. Their finding is supported by component 1 in this study. It talks about the need to consider time students will experience during class meetings. More time in class offers students a greater opportunity to engage in the learning process that will be taking place.

Their third finding (c) was about promotion of activities that have impact beyond the course itself. In this study, this finding is supported by component 8. When activities have an impact beyond the course itself, as stated by Martinez et al. (2017), they can be used by students in other learning situations, be it in other classes of physics, or in the student's professional life, especially in this case where the participants are pre-service teachers. They are teachers in waiting to apply what they have leant in other learning situations.

The difference between this current study and their study lies in the fact that their intention was not to produce design principles as is the case in this study. They did not produce design principle but used principles from other researchers to come up with a model. Yet in this study, the final upgraded intervention obtained after several micro studies is a model that can be suggested for use by others teaching a geometric optics topic or course. Second difference is that they did not test for effectiveness of the intervention, so it is not clear whether their model produced significant achievements or not in their students. Thirdly the number of students they worked with was too small, only 5. Maybe the results could have been otherwise with a large number as was the case of this study.

Kim, Kim, Khera and Getman (2014) conducted a design research in which they set out to produce design principles for a flipped classroom that could be used in diverse disciplinary contexts (chapter 2 section 2.4.4). Their results were six principles. Some procedural aspects in their study were similar to the present study. They used the principles from literature to design an intervention which they then used for teaching. Students' opinion of it were sought through surveys. They did not test the intervention for its effectiveness in terms of student's academic performance, neither did they involve iterations of the initial model. Thus, results of the current study seem to suggest that there is an agreement with the findings of Kim et al. (2017). Their six principles were as follows: (a) *provide clear connections between in-class and out of class activities*, (b) *provide clearly defined and well structure guidance*, (c) *provide enough time for students to carry out the assignments*, (d) *provide facilitation for building a learning community*, (e) *provide prompt/adaptive feedback on individual or group works, and* (f) *provide technologies familiar and easy to access*. In addition to these six principles, they also added three others from Bramer (2013) to make them nine: (g) *provide an opportunity for students to gain first exposure prior to class, (h) provide an incentive for students to prepare for class and* (i) *provide a mechanism to assess student understanding.* The current study findings concur with those of Kim et al. (2017) in the following way:

Table 5. 1: How current study findings support results of Kim et al. (2017)

Current study finding	**Finding from Kim et al.**
1. Identify key ideas in geometrical optics to enable students to understand and transfer their understanding to other learning situations during and after the course.	
2. Planning should consider time, space, and cognitive demand students will experience during and after class meetings.	(b) provide clearly defined and well structure guidance
3. Prepare students for face-to-face class activities, by requiring them to answer a formative quiz, based on video material, provided on time, prior to class meetings.	(f) provide technologies familiar and easy to access. (g) provide an opportunity for students to gain first exposure prior to class (Bramer, 2013) (h) provide an incentive for students to prepare for class (Bramer, 2013)
4. Enhance understanding of key ideas in geometrical optics, through a variety of classroom activities, incorporating real-life implications of theory studied in class, supported by designing and performing relevant laboratory activities.	

5.	Employ strategies requiring peer collaboration and active participation, when solving complex problems in geometrical optics, during and after class meetings.	(d) provide facilitation for building a learning community
6.	Ensure that students use evidence-based reasoned logical arguments, based on key ideas in geometrical optics, when solving complex problems.	(c) provide enough time for students to carry out the assignments
7.	Allow students to take charge of their own learning by developing interest and confidence for solving complex problems.	
8.	Provide assessment activities in line with key ideas of the topic under study, to monitor student progress.	(i) provide a mechanism to assess student understanding. (Bramer, 2013)
9.	Critically and timely, provide students with appropriate feedback on all graded activities, so they can read materials with understanding during and after class meetings.	(e) provide prompt/adaptive feedback on individual or group works, and
10.	Show how different activities students are involved in depend on each other and are organised according to key ideas in geometrical optics.	(a) provide clear connections between in-class and out of class activities

Three findings (1, 4, and 7) of the current study shown in Table 5.1 could not be matched to those of Kim et al. The study by Kim et al. obtained six principles, while the current study had ten. The principles or components in the current study were deduced from participants of various groups, who studied the same content. The results from the study conducted by Kim et al. (2017) were obtained from groups of students enrolled in different disciplines.

Aşıksoy & Özdamlı, (2016) did a study on effectiveness of flipped classroom on three aspects namely learner achievement, motivation and self-sufficiency but not seeking design principles (chapter 2 section 2.4.4). They did not come up with their own model of design but rather an innovation of other researchers' model (Keller, 1987). It was an experimental design in which the performance of the experimental group with flipped classroom was greater than that of the control group. This study concurs with these researchers' findings in terms of the positive effect that flipped classroom has on achievement of learners (see section 2.4.4). However, their study did not produce design principles as is the case in this current study.

A study almost similar in procedure compared to the current study was conducted by Lo and Hew (2017). They also used Merril's (2002) principles as is the case in this study (chapter 2, see section 2.4.4). They also did statistical analysis with t-test to determine the effectiveness of their model on students' performance. They worked with two groups, one for underperformers and the other for high achievers. Both groups showed a significant improvement in the mean scores. Among their findings from the survey conducted was a bit of criticism about how feedback from the teacher was handled. However, they did not seek design principles as is the case in this current study. Lo & Hew (2021) used design-based research and established five design principles: Principle 1- inform the design of a pre class online exercises, Principle 2- inform the design of pre-class online exercises, Principle 3- inform the design of in-class warm-up exercises and a brief review, Principle 4- inform the design of in-class mini-lecture, and Principle 5- inform the design of in-class small group problem solving. The principles inform the design and implementation of instruction at the pre-class learning phase (Principle 1 and Principle 2) and the in-class learning phase (Principles 3, 4 and 5). The current study has also two components focused at the pre-class learning phase and in-class learning phase, which components 3 and 4 respectively, thus supporting the findings of Lo and Hew. The other eight components in this study make propositions on aspects of learning outcomes (component 1), course planning (component 2), peer collaboration (component 5), logical thinking (component 6), self-regulated learning (component 7), assessment tasks (component 8), feedback motivated learning (component 9), and coherence of activities (component 10). The eight components give extra guidance on how to design instruction in areas not touched by the five principles not touched by Lo and Hew (2021).

5.3 GEOMETRICAL OPTICS COURSE DESIGN

5.3.1 How components inform geometrical optics course design

This section addresses the second research question of the study: *How do components of a flipped classroom approach inform the design of a geometrical optics course in physics?*

The components listed in section 5.1 may be used as guiding principles for designing a course in geometrical optics, by using them to design and implement instruction. The list of the components as provided in section 5.1 is arranged in order of priority. The same order was used in this section to explain the role played by each component.

Component 1- Learning goals or outcomes: <u>Identify key ideas in geometrical optics to enable students to understand and transfer their understanding to other learning situations during and after the course</u>.

Component 1 suggests that when designing instruction (development of activities and delivery of information to achieve specific objectives), the first element to be considered should be learning goals or outcomes. The instructor needs to identify what constitutes important content students should learn. From this content, learning goals, objectives, or outcomes for each study unit may be deduced and used to guide instruction. An example of this can be seen in Table 3.4 which shows the design features of the initial intervention used in the instruction of the geometrical optics topic. There are three main ideas under instruction – the ray model of light, refraction of light and reflection of light. These ideas are dealt with as units of study. Under each unit, stage 1 and stage 2 spells out the content to be dealt with and the specific objectives that guide the instruction of the geometrical optics content, respectively. Thus, key ideas must be identified, and the focus should be on achieving understanding of these. If well understood, students will be able to make use of these ideas in any other situations where a learning activity is taking place. Thus, it might be the participants themselves who may be the learners, or they may be teachers professionally. Either way, they must be able to use their knowledge of the key ideas studied in geometrical optics, provided the content under discussion relates to these key ideas. In other words, component 1 requires the teacher to first define the critical content elements the student must understand in geometrical optics, as well as the level of depth at which this content must be dealt with. The issues highlighted in component 1 are attributes associated with FCA. According to AT theory (chapter 2 section 2.5.2), this component is the object of the activity of instruction, which eventually transforms into a bigger outcome of developing competent teachers in the subject of physical science. The object of this activity is part of the bigger motive driving the entire activity. As such, component 1 becomes essential in the design of a geometrical optics course based on FCA framework. In terms of FCA, this component can then be broken down into sub objectives that can be addressed at different phases of instructions, namely-before class phase content objectives, in class content objectives, and after class content objectives. These sub objectives are then addressed following the sub activities organised for each phase.

Component 2-Course activity planning: Planning should consider time, spacing, and cognitive demand of learning activities students will experience during and after class meetings.

Component 2 talks about the need for a plan. According to AT theory, a plan is the means by which the object is achieved. So, it is a conceptual tool that has to be well structured and implemented. Thus, the plan must factor in what has to be done in each of the three phases of FCA. The instructor or teacher needs to design a plan which should guide the activity of teaching and learning. There is need for the instructor to know issues such as- the time needed to complete the syllabus, the appropriate time to teach specific aspects of the content, when the learners are available, etc. There is need to know about the space where the activity takes place, evaluating the space whether it is convenient or not. FCA uses both physical and the virtual space. There is need to know about the physical environment of learning, so that the available furniture and equipment in that environment may be used to the advantage of the student. The instructor in his/her plan, needs to consider cognitive demand- which refers to the state of the mind of the leaners due to the pressure of other academic programmes undertaken by the same students as well.

Component 3- Pre-class learning: Prepare students for face-to-face class activities, by compelling them to answer a formative quiz, based on video material, provided on time, prior to class meetings.

Component 3 identifies three things that are part of FCA that must be included in the design of the course through instruction. Firstly, there is need for students to study before they attend face to face class sessions. Secondly, the use of technology in disseminating the study material to be given to students to study is very important, hence the use of videos where lessons are recorded by the instructor for students to watch before they come to class. The nature of the content on the video material may be as indicated in the second column of Table 3.4 stage 4, where a sequence of videos with content meant to build foundational knowledge (activation), content meant to show how to apply that basic knowledge to simple problems (demonstration) and content meant to perform self-evaluation (application) is watched. Though Table 3.4 served as the initial intervention design model of the study, it also works as a suitable example of how the components of FCA may be used to inform how instruction can be designed in geometrical optics. Thirdly, there must be a way to ensure that the material given to students has been studied before students come to class. This is where the quiz fits in and needs to be written during class but before the actual lesson starts. The video material can be uploaded online or made accessible to students by means of class representatives, but that must happen in ample time for the students to be able to watch it and understand the information. The quiz may also be used as an introductory part of the new lesson planned for that session, as it will be revised, and feedback given immediately. The difficulties students might be having are noted and immediately addressed during the lesson in progress. Alternatively, the quiz may also be online with feedback immediately given to students after completing writing the quiz. According to AT theory (chapter 2, section 2.5.2), the video and the quiz are mediating tools that help students to achieve the goals set, which in this case is component 1 (object).

Component 4- In-class learning: Enhance understanding of key ideas in geometrical optics through a variety of classroom activities, incorporating real-life implications of theory studied in class, supported by designing and conducting relevant laboratory activities.

Component 4 defines what should happen during the face-to-face session. Firstly, there must be different strategies used to engage students with the material to be studied. These must include strategies such as group work, whole class discussions, presentations, and individual work. Secondly, incorporate real-life situations of the theory being studied. Let students be aware of the relevance of the material they are studying in solving real-life problems. Thirdly, make use of laboratory activities to help students understand how the material they are studying are applied in real-life situations. The motive of all face-to-face activities is to ensure that students understand the material in order to transfer their understanding to different situations. Thus, the instructional strategies used at this stage are a means to an end, hence are also tools as defined by AT. According to FCA framework, face-to-face activities are where real understanding of the material should take place, by designing activities that serve to deepen student understanding and application of the key ideas being studied. In table 3.4 stage 4, the proposed arrangement of conducting in-class activities shows three stages: activation, where the instructor gives a brief review of the content under study, after prior knowledge testing and feedback has been given to the students, as well as some demonstration by the instructor on how to apply some of the concepts students studied before the class meeting, then application, where students solve simple problems individually or in pairs, provided on worksheets, and lastly integration, where students discuss the more advanced real-world problems in groups and present their solutions before the rest of the class. Thereafter laboratory work is conducted for students to have a feel of the real-life experience of how the concepts work. The features of the intervention at this stage 4 reflect how component 4 informs design of instructional process of a geometrical optics course.

Component 5- Peer collaboration: Employ strategies requiring peer collaboration and active participation, when solving complex problems in geometrical optics, during and after class meetings.

Component 5 is intended to make students aware that there is benefit in working collaboratively than working as an individual. It is a quality to be developed in the student through the type of activities to which the student is exposed. Thus, while component 4 talks about using strategies that enhance understanding of the key ideas in geometrical optics, component 5 requires that students be given the opportunity to work together with peers in groups, where they feel free to make personal contributions, as part of a larger community working towards a common good. In collective effort ideas are interchangeable, misconceptions are revealed and could be addressed, with the help of peers and the instructor. The outcome could be far more reaching than that of an individual alone. Once the student is aware of this, the student would be more likely to consult his / her peers or instructor, or the librarians. According to the FCA framework, this component suited for both in class and out of class activities. While students may work through group activities in class, they may also continue after class communicating through WhatsApp if direct meetings are impossible, such as in current pandemic error of corona virus. According to AT, this component is part of the social base of the activity system comprising of rules, the community, and the division of labour. The social base identifies an individual as a social entity who thrives in the environment of his community. The student through interchange of ideas with the academic community to which he / she belongs could be able to achieve his / her goals. Thus, an individual is formed by the society he / she belongs to. The concerted effort of the peers, instructor, and other academic staff to which the student belongs could bring the greater outcome, in this case, of becoming a competent science teacher. Thus, the student becomes actively involved at individual level, in the work in which the greater majority of the community to which he / she belongs is involved in. It should be noted that component five and component four work together, especially where complex problems are involved, and at times also with component one. This can be seen in the design features of the intervention in Table 4 (learning arrangements stage 4, in-class and before class, respectively).

Component 6- Logical reasoning: Ensure that students use evidence-based reasoned logical arguments, based on key ideas in geometrical optics, when solving complex problems, so they can take charge of their own learning.

While component four deals with mastering and understanding of key ideas, and component five requires that the process of acquiring the targeted objectives be collective, component six seeks to develop critical thinking skills in the process of learning. The instructor has to make it a requirement or a rule in all activities of higher cognitive demand for students to meaningfully support their reasoning with evidence of scientific facts available. Such an approach to learning is meant to develop student ability to scrutinise the material they will be reading and take out essential information as facts used to support their arguments during class discussions, writing of tests or examinations. Thus, be it problems requiring calculations, students must be able to correctly justify the steps followed. When students are able to reasonably defend their ideas, they are likely to be confident, develop interest in the subject, and could even be motivated to study further. Thus, students take charge of their own learning (Zimmerman, 1990; Panadero, & Alonso

Tapia, 2014). In terms of FCA, the component is applicable to all types of activities given before, during and after class. In terms of AT, the component is a conceptual tool. It guides instructors on how to develop student understanding of the subject matter. Students are required to interrogate any type of study material they engage with, even peers, the instructor, or other members of the academic community within their discipline. Thus in the design of a geometrical course, this component informs the design of in-class activities, hence works well with component 4.

Component 7- Self-regulated learning: Allow students to take charge of their own learning by developing interest for, and confidence in solving complex problems.

Component seven is about self-motivated learning. It talks about how to make a student become aware of the need to actively engage in academic work without being pushed to do so. It talks about the need for the instructor to design strategies that promote self-regulated learning in students, in which students learn intentionally and effectively (Panadero, & Alonso Tapia, 2014). Students are driven by the need to achieve the goals they intentionally set up themselves, hence design their own strategies to achieve these goals. Component seven indirectly promotes the use of learning strategies that engage students in deeper learning. According to AT theory, it is a conceptual tool that could be used to achieve academic excellence. Within the FCA framework, component seven is suited for all its learning phases. A self-regulated student is likely to be purposely working on academic tasks, that are self-initiated, be it prior, during, or post class meetings. Thus in the design of instruction for a geometrical optics course, this component informs the instructor to design learning environments that promote a self-drive in students, aimed at achieving the bigger learning outcome. As such, this component informs the instructor the need to be student-sensitive at all times when designing a geometrical optics course, such as provided in Table 3.4 and Table 5.2.

Component 8- Graded activities: Provide assessment activities that are in line with key ideas of the topic under study, to monitor student progress.

Component eight is about how assessment activities should be conducted. The assessments are for monitoring student progress. The quantity must be sufficient enough to enable the instructor to make reasonable judgements. Usually these are determined by the curriculum document followed, but there could be more depending on how the instructor evaluates the student's performance. The assessments should be testing for an understanding of the key ideas defined in the objectives as identified by component 1. Formative tasks are born out of assessment activities as tools for measuring the extent of progress achieved by students. Thus, in terms of AT, assessments are mental tools to measure the level of conceptual understanding in the student. When it comes to FCA, for each of its three phases, assessments can be designed for the before class activity, such as the quiz to be written online or in class at the beginning of a lesson. They can be designed for the in-class activities, such as group work that has to be submitted or presented during class and marks are awarded, or for an after-class activity as an assignment to be submitted at a given time. Thus, the principle provides the opportunity to design a number of formative assessments, for any activities designated for each of three phases of the FCA. Component 8 also informs how validity of the graded activities or assessments of the geometrical optics content may be achieved. Components 8, 1, 2 and 4 are highly interrelated. Planning for the instruction must ensure that goals, instructional activities and assessment activities are inline. Thus stages 2, 3 and 4 of Table 3.4 must be designed taking into consideration the influence these components have on the successful implementation of the others. Thus the planning of instruction must carefully accommodate all four components. In this way validity of the assessment activities can be achieved.

Component 9- Feedback learning: <u>Critically and timely, provide students with appropriate feedback on all graded activities, so they can read materials with understanding during and after class meetings.</u>

Component nine is a loaded statement about how feedback should be treated. The first aspect identified by this component is that there should be feedback in the instructional activity as part of the course design. Students need to know what is wrong and what is right in their responses. The second aspect identified in this statement is that the feedback is not only for a selected few activities, but for any written activity given to students with the purpose of monitoring progress. Thus, the instructor has to carefully plan how many assessments he / she intends to give the students, for none of these activities must be ignored when it comes to providing feedback. The third aspect in this statement is that the feedback has to be appropriate. Each student is a different entity who may have different needs (which includes different cognitive levels) compared to others. The feedback must be given accordingly to these needs. Thus, there is a need to look at characteristics of the students and seek ways to effectively guide them on what to do according to their needs as reflected by the results of the assessment written by them. The fourth aspect noted in the statement is that the feedback must be given timely. It must be given when the students can mostly benefit from the advice given by the instructor so that remedial action can be conducted in time for meaningful learning to take place. The fifth aspect is that the feedback must be given critically:-meaning the instructor must consider the weaknesses and strengths of the responses given by the student and the student made aware them. The last aspect is that as part of the remedial action regarding feedback, it must be directed to the student to do some reading - or further studies with the purpose of understanding the content, not just for the sake of writing tests and exams to pass, otherwise what the first component proposes will not be achievable. In terms of FCA, one of the benefits of instruction designed based on FCA framework is that FCA tends to create more time for learning, as learning continues outside the classroom where minor aspects of the content are dealt with individually or in group work, while the class time is dedicated to explore the content deeper. Thus, component nine seeks to bring awareness to both the instructor and the student to address the most important issues in class, and for the student to continue further with the same important issues even outside the classroom. This is how they create more time to deal with content at a deeper level. In terms of AT, feedback should be a conceptual tool meant to achieve deeper understanding of the content, as the instructor delves into the nitty-gritties of what the student is missing and must do to fill in the gaps. Thus component 8 fits to identify what should be done in all three phases of the FCA-based course design. Component 9 informs what kind of feedback must be given, how that feedback must be delivered, when and where it is appropriate to deliver it, hence strongly compliments component 8. It helps to inform what formative assessments designed for each of the three phases of FCA should take into account when incorporating them in the design of a geometrical optics instructional model, such as the ones shown in Tables 3.4 and 5.2, especially at stages 3 and 4 where specific activities and tasks in geometrical optics will be conducted with the aim of achieving the specific goals and objectives highlighted by component 1.

Component 10- Coherence of activities: <u>Show how different activities students are involved in, depend on each other, and are organised according to key ideas in geometrical optics.</u>

Component ten suggests the need to develop awareness in the students about how all the activities they are involved in tend to support each other. The activities are not isolated events but are based on and organised according to the key ideas identified in component 1. Since the key content ideas themselves build upon each other, the activities likewise must be seen to build upon each other, thereby showing how they depend on each other and integrated they are. Within the FCA framework, the phase before class meetings is used to prepare for the next phase, which is face-to-face sessions, where content is dealt with at a deeper level. The phase before the class meetings (face-to-face session), is simply for introducing the basic information to students, provided in the form of lectures captured using video technology. This phase is an activity on its own from which the face-to-face session depends upon. If students are not well prepared in this first phase, the in-class phase becomes a failure because the instructor will have to ensure students have mastered the basic facts first from which the complex concepts are built upon. The third phase which is the after-class phase serve to consolidate what has been developed in class, so that students do not forget easily. In this third phase a continuation of problems or activities initiated during the face-to face session takes place where students complete the tasks as homework. This will be another activity on its own. Even laboratory practical activity may be an activity on its own but serves to build understanding of the theory discussed in class. Thus, students must be made aware of the linkage through various tasks they have to answer, how one task leads to the other. All the activities have a common purpose of achieving a greater depth of understanding of the key ideas being studied. In terms of AT, the organisation of these ideas and activities to achieve a common purpose make it a conceptual tool mediating between the subject (the student) and the object (understanding of the key ideas).

In broader perspective, component 10 brings an awareness to geometrical optics course designers that all components discussed in this section are in one way or another related to one another. In designing the course, one activity must serve to promote the successful implementation of the next. Since each component serves to inform the design of a particular aspect of the course, component 10 informs of the need for alignment of all activities. Thus all stages in Table 3.4 must serve to complement each other. The course-design features of the intervention shows that the intervention divides the course into three key ideas: ray model of light, refraction of light, and reflection of light. Each of these ideas is not isolated from the others but the understanding of one leads to the understanding of the others. The way at which these ideas (or units) are sequenced during instruction will either help or not students to achieve a greater understanding of the entire topic. In accordance to the design structure of the intervention, the ray model was considered important to start with so that when dealing with geometrical shapes in refraction and reflection, it becomes easier for students to understand how these shapes are formed using optical instruments. Thus coherence among these three topics is reflected in one unit’s activities supporting or being supported by ideas from the other two units.

It is also important to note that modifications of the intervention based on feedback from student participants also informed the second research question. Student participants’ feedback mainly centered on instruction (i.e. managing the instructional process), videos material, class discussions, and assessment strategies (see Table 4.30). Views from student participants related to these four areas helped in the redesigning of revised versions (such as Table 5.2) of the original instructional intervention (Table 3.4), from which components discussed in this section were deduced. As such, the discussion on how these components may be used to inform the design of a geometrical optics course, indirectly shows how modifications of the intervention based on feedback from student participants informed the second research question as well.

5.4 EFFECTIVENESS OF THE INTERVENTION

The pilot intervention designed in 2015 was constantly improved and used with each new cohort of students. This section addresses the third research question in this study: *What is the effect of the intervention on students' performance in geometrical optics in physics?*

Students' conceptual understanding of geometrical optics content was measured using the LOCE instrument. The results of this study found that the FCA based intervention had a significant effect on student performance (see section 4.7, Table 4.27). For the 2017 student cohort, the adjusted post mean score was 14.93 and that of 2018 was 17.67, while that of 2019 was 17.36. A further analysis (see section 4.7, Table 4.28) to determine the specific groups on which the intervention led to the differences in students' learning, between the student cohorts of 2017, 2018, and 2019, when compared pairwise in terms of mean differences in achievement (determined using post-score means), statistically significant differences in achievement were noted between groups of 2017 and 2018 (2.74, $p < 0.05$) as well as those of 2017 and 2019 (2.42, $p < 0.05$). Though there were some differences in performance between groups of 2018 and 2019, the difference was not statistically significant (0.32, $p = 1.00$). These findings show that the intervention was statistically more effective with the 2018 and 2019 cohorts of students than in 2017. In other words, the results of the ANCOVA show how the effectiveness of intervention changed with the introduction of changes in the intervention. The effectiveness of the intervention was authenticated by the calculation of the normalized gain.

The results of the current study support the findings of the study made by Martinez, Lombaerts and Celeya (2017). These researchers worked with five undergraduate students in computational physics. After implementation of their instructional intervention, which was designed on FCA based framework, they found that all students received good grades on the tasks they were asked to accomplish. However, their findings were not based on any performance of any statistical analysis.

A study conducted by Asiksoy and Ozdamli (2016) tested the effect of FCA on learner achievement, among two other aspects of learning of motivation and self-sufficiency, using two groups of students: - an experimental group and a control group. The post-test scores of the experimental group were significantly higher than those of the control group. Their results are supported by the findings of the current study. Their intervention was effective in improving learning. Therefore, the findings of this current study support the findings of Asiksoy and Ozdamli (2016).

Low and Hew (2017) conducted a study with 37 group of secondary school students using FCA. Two groups were formed, one for underperforming students and another of high ability students. The analysis of data in their study involved the use of t-test. Their findings revealed a significant improvement in achievement scores for both groups of students. The study findings of Lo and Hew (2017) show that interventions designed on a FCA based framework can improve student performance. The findings of the current study showed there was statistically significant difference in performance between groups of 2017 and 2018, and between groups of 2017 and 2019. There was also difference in performance between groups of 2018 and 2019 but not statistically significant. For groups of 2017 and 2018, the difference is likely due to the improvements made on the weaknesses of the intervention identified in 2017, which were then used to improve the teaching intervention, thereby resulting in improved performance in the results of the group of 2018. The difference between the group of 2018 and 2019 was also likely to be due to changes effected on the previous intervention of 2018, leading to a slight improvement in performance of the group of 2019, as compared to that of 2018. However the difference was not statically significant, most likely because of saturation. Changes were being effected from 2015 to 2018. Changes of 2018 were minor as most of the shortcoming pointed out by this group had been incorporated in previous interventions. The focus now was on how to improve on all shortcomings identified before. The current study findings support the study findings of Lo and Hew (2017).

In conclusion it can be seen that the findings of the current study concur with those found in the literature, that the FCA based intervention did indeed improve student performance during its implementation. The extent to which each group was influenced may be different, but the findings presented provided support that there was a significant improvement in students' performance in some of the groups. The little difference between groups of 2018 and 2019 may be due to the fact that there were no major differences between the modified interventions of 2018 and 2019. As such, students' performance did not differ much between these two groups.

5.5 IMPLICATIONS OF THE STUDY FINDINGS

5.5.1 Contribution of the study to the body of knowledge

Findings of this study showed that the FCA based intervention had a significant effect on students' learning. The study was conducted to address a gap in literature as argued by O'Flaherty and Phillips (2015). These authors pointed out six issues that literature needed to address about the FCA, if a curriculum transformation by educators was to take place (see chapter 2 section 4.5.2): According to O'Flaherty and Phillips (2015, p. 94)

a. *The under-utilisation of conceptual frameworks that enable a united approach to pre-, F2F and post-learning activities, resulting in a lack of clarity and heavy content focus.*
b. *An under-developed capacity to blueprint, that is, to translate conceptual frameworks into context-specific plans*
c. *The lack of understanding of how to design and support inquiry-based learning and metacognition in a flipped learning curriculum.*
d. *The need for stronger evidence in evaluating student learning outcomes that particularly improved student learning and development, as critical thinkers, problem solvers and team players*
e. *The need to stimulate higher order thinking using creative technologies and applied learning*
f. *The need for guidelines about current approaches to assessment and feedback, e.g., writing quality learning checkpoints (in pre- and/or F2F sessions).*

The first implication of the findings of the current study is that the components are a guide on how to design a course in geometrical optics. The components were drafted in a manner which is more detailed than those in the literature that has been discussed in this study. Section 5.3 provides more details on how each component may be used to inform the design of a FCA based course for the benefit of the classroom practitioners.

The second contribution is that the nine components of FCA found in this study attempt to address the issues raised by O'Flaherty and Phillips (*a to f*). The issues may not be directly linked to each of the components but an overview of the whole set of components shows that the components are touching specifically on the concerns of O'Flaherty and Phillips. As such this study addresses a knowledge gap in literature. The current study contributes to theory needed by researchers.

The third contribution to the body of knowledge is deduced from the number of components in this current study, as compared to the number proposed by other researchers in literature (Kim, Kim, Khera & Getman, 2014; Lo, Hew, Chen, 2017; Lo & Hew, 2021). In Table 5.1, component 1 and component 4 could not be matched to the results of other studies in literature. As such this provides new knowledge to the design principles needed for a geometrical optics course design. These two components demand the identification of the big ideas needed to be developed in the student, and how these ideas are to be developed during class discussions, respectively.

The fourth contribution is on practical basis, the model defined in chapter 3, (section 3.4.1.2) used in this current study may be modified or adopted for use in class, for teaching geometric optics, as indicated in Table 5.2, thus providing a solution to an immediate practical problem of how to teach an undergraduate geometric optics course, under similar conditions.

Table 5. 2: Sample model of a unit for teaching geometrical optics

Unit 1: The ray model of light

Purpose:

This unit aims to develop in the student a greater understanding of the concept of ray model of light in geometrical optics, by applying it to complex physical situations that combine multiple aspects of physics than presenting concepts in isolation. Due to the complex nature of light, the ray model of light simplifies the subject matter of optics, by describing light in simpler terms. Using the ray model of light enables discussions about the path taken by light, analysis of many devices and other phenomena, without committing to any specific description of what it is that is moving along that path or interacting with the devices.

Content:

Discussion of the concept of light in terms of the three models of light:

- The ray model & its assumptions
- The wave models
- The particle model

Learning outcomes

On completion of the course unit students should be able to demonstrate knowledge and understanding of the concept of the ray model of light, so they can:

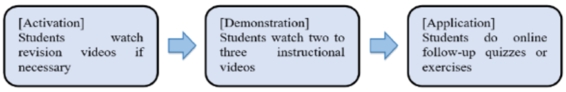
- Define the concept of *ray of light*
- State and interpret the assumptions of the ray model of light
- Correctly predict the behaviour of light when interacting with a transparent material medium
- Explain how observers at different locations may be able to see the same object at the same time
- Explain why it is impossible to separate a single ray of light from a beam of rays

Assessment activities

Students:

- Write an open-ended short quiz about the ray model during class time, first lesson after orientation class. Video lecture content is posted on BB prior to writing the quiz (duration 20 minutes). Quiz meant to motivate students to watch and study content on video lectures.
- Write a one hour open ended test at the end of the study unit.
- Design, Conduct & Complete lab investigations and reports respectively, for each study unit

Proposed learning arrangements for the pre-class phase



Activation

- Provide video lectures explaining the concepts of the ray model of light and its assumptions, the wave model, and the particle model- with the aid of diagrams

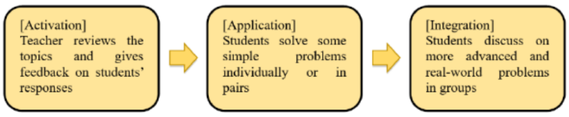
Demonstration

- Provide video lectures demonstrating the use of the models of light in solving simple problems involving models of light

Application

- Include simple exercises for students to work on their own in each of the video lectures

Proposed learning arrangement for the face-to-face phase



Activation

- Provide a short quiz on ray model, wave model, and particle models of light, to be written by students which should contribute to their course work mark.
- Revise the quiz immediately after writing it and use it to provide a brief review of content placed on video lectures

Demonstration

- Demonstrate how to solve some problems before the whole class, and thereafter allow students to work on their own or in pairs, problems which are not too difficult on models of light

Application

- Provide students a worksheet of problems on models of light and their assumptions which are more challenging than in the previous case, to be solved in groups of 5 members

Integration

- Thereafter the groups present their solutions fully explaining the procedure before the class in front of other classmates so their findings can be peer reviewed, guided by the lecturer as facilitator

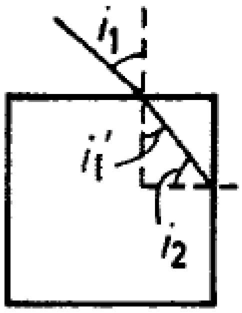
Proposed learning arrangements for the after-class phase

Consolidation phase

- Students continue to work and complete physics problems on work sheet
- Students & lecturer form a learning community to share ideas on how to address challenges encountered when solving physics problems on worksheet
- Make use of social media or other means of communication, with well-guided rules, for consultations with each other

Sample problems

1. A glass cube has a refractive index of **1.5.** A light beam enters the top face obliquely and then strikes the side of the cube. Does light emerge from this side? Explain **your** answer. (Yung-kuo, 1991, p. 5)



The student is not only expected to perform calculations but to use them to reason and justify on the outcome when the calculations are compared to the refractive index of the material.

2. A line object **5** mm long is located 50 cm in front of a camera lens. The image **is** focused on the film plate and ***is*** 1 mm long. If the film plate is moved back 1 cm the width of the image blurs to **1** mm wide. What is the F-number **of** the lens? (Yung-kuo, 19191, p. 12)

3. A spherical concave shaving **mirror** has a radius of curvature **of 30.5 cm**. What is the magnification when the face is 10.2 cm from the vertex of the mirror? Include a ray diagram of the image formation. Yung-kuo, 1919, p. 20)

5.6 LIMITATIONS OF THE STUDY

The strength of this current study lies in the fact that the data itself has been triangulated in an attempt to improve its reliability, through both quantitative and qualitative data, acquired using three different instruments. In addition to this, the iteration process with multiple groups of student participants tend to improve the validity of the data used to reach the findings stated. Thus, the methodological procedure followed by the study tends to increase rigor of the findings.

However, all studies have limitations. It is necessary to point out the limitations of the study for the sake of identifying areas where further studies may be needed, or for those who may need to make use of the findings to be able to decide based on its strength and weaknesses.

One of the limitations is that the entire study was done in one university with one instructor and lack of teaching assistants. The institution constantly enrolled a large number of students, and one instructor taught the large groups each consecutive year. Taking into consideration that FCA is a new instructional approach still developing, and the instructor had no prior training on how to deal with it, using the FCA with a large number of student participants each year and for the first time, may have challenges at the time of implementation, which may affect the final results of the study. It was also the first time the institution had handled such type of an instructional approach.

It is also important to note that all activities ran by the institution had to fit within the time frame allocated to each programme. In addition to attending their physical science course, students had to attend their teaching practice sessions which required them to be out of the campus for a month and half, while at the same time handling lessons distance wise, unlike their counterparts who were studying physics in the hard sciences faculty, who were always at the campus. Unfortunately, for student participants involved in this study, this situation created shortage of time needed to adequately cover the content. Each group of participants raised the same issue of shortage of time each year, which became a limitation to the study. Performance may probably have been different with adequate time sought out by students.

Another institutional problem was related to facilities available to run the flipped classroom instruction approach. The lack of facilities included rooms big enough to handle large numbers of students, where students could be seated in groups of four or five at round tables for discussions and carrying out demonstrations. At times blackboard facilities were not efficient enough for participants to access material in time for adequate preparation for class meetings. The same instructor, with the large group, was conducting laboratory activities. This reduced time for class meetings because it took more time to conduct the laboratory sessions with all students. At times some of the practical activities were left out because of shortage of time. Thus, such issues as raised in this paragraph may improve the results of the study if adequately addressed.

Another challenging factor, especially in a study involving second language learners is the language problem (Tichapondwa, 2013). In this study, the student population at the university where the study was conducted use the English language as a second language. This was a problem because it created a language barrier at the time when students had to express their ideas before the class during class discussion sessions. It was also a problem when students had to answer questions in written format. Though it was not all of the students who had serious issues in this regard, but those caught in this dilemma would struggle to bring out meaningful ideas of what they intended to say. The instructor had to go to a greater extend to explain what students were expected to do in tasks given to them as exercises through work sheets or during class discussions. In trying to mitigate the problem by taking this approach, there were also consequences such as failure to complete scheduled tasks for the class. Eventually the instructor had to reschedule some of the tasks meant for the class as homework after the class. The other issues that need consideration are the following:

- The study was conducted largely focusing on higher education contexts. Most of the articles used in the study where from higher education contexts.
- The participants involved in this study were all undergraduate students, most with a rural background from the African culture. These findings are therefore context-specific, and one may need to modify them in order to apply them in other contexts.
- The study was conducted following a specific definition of a flipped classroom that considered the use of videos as the main technological component (Bishop & Verleger, 2013) thus avoiding definitions that do not consider technology.

5.7 CONCLUSION AND RECOMMENDATIONS

The findings of the current study were an attempt to address three research questions that guided the study (see section 5.1). The study findings for the first research question were ten components of FCA (see section 5.2). The components address ten key elements in the context of flipped learning, namely learning goals or outcomes, course activity planning, pre-class learning, in-class learning, peer learning, logical reasoning, self-regulated learning, graded activities, feedback learning and coherence of activities. The second research question sought to find out how the components could be used to inform the design of a geometrical optics course. In section 5.3.1, the second research question was addressed, with each of them being explained on how it relates to FCA, and how it can be possibly used to guide instructional design. The third research question sought to find out what the impact of the designed intervention was on students' performance (see section (5.1). In section 5.4, the question was addressed, in which it was shown that performance of participants was statistically significant, meaning the designed intervention impacted positively on students learning. Thus, the findings of this study may be taken to have impacted positively on students learning of the course and may be used for designing courses in geometrical optics but taking into considerations of the limitations indicated in section 5.6. A model was also provided on how the actual intervention design could look like (see section 5.5.1, Table 5.2), which could be adopted by those who may be interested. However, there were also negative issues raised in qualitative interviews that may have impacted on the effectiveness of the intervention. Such issues include workload-related time constraints, video challenges, challenges related to poorly resourced large class size, incorrect perceptions about the rationale behind the use of video content and challenges with terminology used in physics language.

Recommendations- There were also issues raised around the limitations of the study (section 5.6). These issues are an acknowledgement that no investigation is purely perfect, and as such the current study, while it has its own strengths, it also has its own weaknesses. Any further future studies may have to look at the following recommendations:

1. That the study be conducted at different institutions with different instructors but following the same curriculum.
2. That where a large number of students is involved, there should be more than one teaching assistants.
3. That the study be conducted both with students who are not second language speakers, as well as those who have good command of English, so that the effects of language handicap may be noted as well. This study was conducted with students who spoke English as a second language, hence struggled with expressing themselves.
4. That there be training at institutions of learning in the use of FCA to instructors, to improve the efficiency in its design and delivery.

REFERENCES

Abimbola, I. O., & Baba, S. (1996). Misconceptions & alternative conceptions in science textbooks: The role of teachers as filters. *The American Biology Teacher*, 14-19.

Afifi, M. K., & Alamri, S. S. (2014). Effective principles in designing e-course in light of learning theories. *Turkish Online Journal of Distance Education*, *15*(1), 128-142.

Ahmed, M. A. E. A. S. (2016). The effect of a flipping classroom on writing skill in English as a foreign language and students' attitude towards flipping. *US-China Foreign Language*, *14*(2), 98-114.

Alarcon, M., Lakhdar, Z. B., Culaba, I., Lahmar, S., Lakshminarayanan, V., Mazzolini, A. P., ... & Niemela, J. (2010, August). Active learning in optics and photonics (ALOP): a model for teacher training and professional development. In *Optics Education and Outreach* (Vol. 7783, pp. 8-15). SPIE.

Alharahsheh, H. H., & Pius, A. (2021). Exploration of Employability Skills in Business Management Studies Within Higher Education Levels: Systematic Literature Review. *Research Anthology on Business and Technical Education in the Information Era*, 1147-1164.

Alshenqeeti, H. (2014). Interviewing as a data collection method: A critical review. *English linguistics research*, *3*(1), 39-45.

Amiel, T., & Reeves, T. C. (2008). Design-based research and educational technology: Rethinking technology and the research agenda. *Journal of educational technology & society*, *11*(4), 29-40.

Andreou, C., & Raftopoulos, A. (2011). Lessons from the History of the Concept of the Ray for Teaching Geometrical Optics. *Science & Education*, *20*(10), 1007-1037.

Arons, A. B., & Redish, E. F. (1997). *Teaching introductory physics* (p. 362). New York: Wiley.

Asenahabi, B. M. (2019). Basics of research design: A guide to selecting appropriate research design. *International Journal of Contemporary Applied Researches*, *6*(5), 76-89.

Aşıksoy, G., & Özdamlı, F. (2016). Flipped Classroom adapted to the ARCS Model of Motivation and applied to a Physics Course. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(6).

Atkinson, R. D., & Mayo, M. J. (2010). Refuelling the US innovation economy: Fresh approaches to science, technology, engineering, and mathematics (STEM) education. *The Information Technology & Innovation Foundation, Forthcoming*.

Bain, K., & Siddique, M. N. A. (2017). Organization of contents in intended junior secondary science curriculum of Bangladesh: An explorative study. *Science Education International*, *28*(2).

Baker, J. W. (2000). The" classroom flip. *Using web course management tools to become the guide by the side*, 9-17.

Bakker, A. (2018). *Design Research in Education: A Practical Guide for Early Career Researchers*. Routledge.

Barab, S. A., Evans, M. A., & Baek, E. O. (2004). Activity theory as a lens for characterizing the participatory unit. *Handbook of research on educational communications and technology*, *2*, 199-213.

Barab, S. (2014). Design-based research: A methodological toolkit for engineering change. In *The Cambridge Handbook of the Learning Sciences, Second Edition* (pp. 151-170). Cambridge University Press.

Bates, B. (2019). *Learning Theories Simplified:... and how to apply them to teaching*. Sage.

Bates, S., & Galloway, R. (2012, April). The inverted classroom in a large enrolment introductory physics course: a case study. In *Proceedings of the HEA STEM learning and teaching conference* (Vol. 1).

Bergmann, J. (2011). *The flipped class blog: The history of the flipped class. The Flipped Class Blog,* Retrieved from: URL:http://blendedclassroom.blogspot.com/2011/05/history-of-flipped-class.html

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. International society for technology in education.

Berrett, D. (2012). How 'flipping the classroom can improve the traditional lecture. *The chronicle of higher education*, *12*(19), 1-3.

Bishop, J. L., & Verleger, M. A. (2013, June). The flipped classroom: A survey of the research. In *ASEE National Conference Proceedings, Atlanta, GA* (Vol. 30, No. 9, pp. 1-18).

Blizak, D., Chafiqi, F., & Kendil, D. (2009, June). Students misconceptions about light in Algeria. In *Education and Training in Optics and Photonics* (p. EMA5). Optical Society of America.

Bhattacherjee, A. (2012). *Social science research: Principles, methods, and practices*. University of South Florida.

Bowen, G. A. (2008). Naturalistic inquiry and the saturation concept: a research note. *Qualitative research*, *8*(1), 137-152.

Braeken, J., & Van Assen, M. A. (2017). An empirical Kaiser criterion. *Psychologica Methods*, *22*(3), 450.

Brame, C., (2013). *Flipping the classroom*. Vanderbilt University Center for Teaching. Retrieved from http://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom/.

Brewerton, P. M., & Millward, L. J. (2001). *Organizational research methods: A guide for students and researchers*. Sage.

Bueche, F. J., and Hecht, E., (1997). *Schaum's outline of Theory and Problems of College Physics* (9^{th} ed.) The McGraw-Hill. https://www.academia.edu/34917684/Schaums_Outline_of_College_Physics_9thEd_Bueche_and_Hecht_pdf

Burnard, P., Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Analysing and presenting qualitative data. *British dental journal*, *204*(8), 429-432.

Cable, S., (2015). *Design principles-a guide*. Cxpartners. Retrieved January 6, 2022, from https://www.cxpartners.co.uk/our-thinking/design-principles/.

Carroll, S., (2015). *Getting started with the SENCER-SALG*. SENCER Summer Institute 2015. Retrieved June 26, 2021, from http://ncsce.net/wp-content/uploads/2016/10/SALGSlides.pdf

Cohen, L., Manion, L., & Morrison, K. (2018). Research methods in education (eight edition). *Abingdon, Oxon*.

Çokluk, Ö., & Koçak, D. (2016). Using Horn's Parallel Analysis Method in Exploratory Factor Analysis for Determining the Number of Factors. *Educational Sciences: Theory and Practice, 16*(2), 537-551.

Collado-Valero, J., Rodríguez-Infante, G., Romero-González, M., Gamboa-Ternero, S., Navarro-

Soria, I., & Lavigne-Cerván, R. (2021). Flipped classroom: Active methodology for sustainable learning in higher education during social distancing due to COVID-19. *Sustainability*, *13*(10), 5336.

Costello, A. B., & Osborne, J. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical assessment, research, and evaluation*, *10*(1), 7.

Crawford, K., & Hasan, H. (2006). Demonstrations of the activity theory framework for research in information systems. *Australasian Journal of Information Systems*, *13*(2), 50.

Creswell, J. W., (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed). Sage publications.

Center for Teaching Excellence (2015). *The flipped classroom*. White paper. University of Waterloo. https://uwaterloo.ca/centre-for-teaching-excellence/sites/ca.centre-for-teaching-excellence/files/uploads/files/the_flipped_classroom_white_paper.pdf

Daniels, R. (2007). Skills shortages in South Africa: A literature review.

Demiraslan, Y., & Usluel, Y. K. (2008). ICT integration processes in Turkish schools: Using activity theory to study issues and contradictions. *Australasian Journal of Educational Technology*, *24*(4).

Demirel, E. E. (2016). Basics and key principles of flipped learning: Classes upside down. *International Journal of Languages, Literature and Linguistics*, *2*(3), 109-112.

Department of Basic Education, (2011). *Curriculum and Assessment Policy Statement*. Retrieved from https://www.education.gov.za/Resources/Reports.aspx

Department of Basic Education, (2014). *Annual Report* 2013/14. Retrieved from https://www.education.gov.za/Resources/Reports.aspx

Department of Basic Education, (2016). *Annual Report*. Retrieved from https://www.education.gov.za/Resources/Reports.aspx

Derry, S. J., Hackbarth, A., & Puntambekar, S. (2018). A Cyberinfrastructure for Design-Based Research: A Collaborative Design Project Proposal. WCER Working Paper No. 2018-14. *Wisconsin Center for Education Research*.

Doubleday, A. F., & Wille, S. J. (2014). We are what we do: Examining learner-generated content in the anatomy laboratory through the lens of activity theory. *Anatomical sciences education*, *7*(5), 361-369.

Drysdale, J. S., Graham, C. R., Spring, K. J., & Halverson, L. R. (2013). An analysis of research trends in dissertations and theses studying blended learning. *The Internet and Higher Education*, *17,* 90-100.

Dudley-Marling C. (2012). Social Construction of Learning. In: Seel N.M. (eds) *Encyclopedia of the Sciences of Learning*. Springer, Boston, MA. https://doi.org/10.1007/978-1-4419-1428-6_96

Ebora, A. (2016). Academic performance in physics of fourth year high school students in one public high school in Batangas City, Philippines. *Asia Pacific Journal of Education, Arts and Sciences, 3*(3), 36-40.

Elangovan, N., & Sundaravel, E. (2021). Method of preparing a document for survey instrument validation by experts. *MethodsX*, *8*, 101326.

Engeström, Y. (1999). Activity theory and individual and social transformation. *Perspectives on activity theory*, *19*(38), 19-30.

Estes, M.D., Ingram, R., Liu, J.C., (2014). A review of flipped classroom research, practice, and technologies. *International Higher Education Teaching and Learning Association*. July 29, (4).

Evanouski, L. (2009). The impact of technology in education: A synthesis paper on technology in education. *Educational technology 501*.

Finkenberg, F., (2017). Flipped classroom in secondary school physics education. Retrieved from https://www.researchgate.net/publication/322356981.

Foot, K. A. (2014). Cultural-historical activity theory: Exploring a theory to inform practice and research. *Journal of Human Behavior in the Social Environment*, *24*(3), 329-347.

Fox, N. (2009). Using interviews in a research project. *The NIHR RDS for the East Midlands/Yorkshire & the Humber*, *26*.

Frigg, R., & Nguyen, J. (2017). Models and representation. In *Springer handbook of model-based science* (pp. 49-102). Springer, Cham.

Galili, I., & Hazan, A. (2000). Learners' knowledge in optics: interpretation, structure and analysis. *International Journal of Science Education*, *22*(1), 57-88.

Gedera, D. S., & Williams, P. J. (2015). *Activity theory in education: Research and practice*. Springer.

Gibbons, J. F., Kincheloe, W. R., & Down, K. S. (1977). Tutored videotape instruction: a new use of electronic media in education. *Science*, *195*(4283), 1139-1146.

Goldberg, F. M., & McDermott, L. C. (1986). Student difficulties in understanding image formation by a plane mirror. *The Physics Teacher*, *24*(8), 472-481.

Goldberg, F. M., & McDermott, L. C. (1987). An investigation of student understanding of the real image formed by. *Am. J. Phys*, *55*(2), 2.

Goodyear, P. (2015). Teaching as design. *Herdsa review of higher education*, *2*(2), 27-50.

Gravemeijer, K., & Prediger, S. (2019). Topic-specific design research: An introduction. *Compendium for early career researchers in mathematics education*, 33-57.

Gürel, D. K., & Eryilmaz, A. (2013). A content analysis of physics textbooks as a probable source of misconceptions in geometric optics. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *28*(28-2), 234-245.

Hadzibegovic, Z., & Slisko, J. (2013). Changing university students' alternative conceptions of optics by active learning. *CEPS Journal*, *3*(3), 29-48.

Hair, J., Andreson, R., Tatham, R., & Black, W. (1998). Multivariate data analysis. 5th (ed) Prentice-Hall Inc. *Unites States of America*.

Hair Jr, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2010). SEM: An introduction. *Multivariate data analysis: A global perspective*, *5*(6), 629-686.

Hamdan, N., McKnight, P., McKnight, K., & Arfstrom, K.M., (2013). The flipped learning model: A white paper based on the literature review titled a review of flipped learning. Flipped learning network. Pearson. George Mason University.

Henson, R. K., & Roberts, J. K. (2006). Use of exploratory factor analysis in published research: Common errors and some comment on improved practice. *Educational and Psychological measurement*, *66*(3), 393-416.

Herrington, J., Reeves, T. C., & Oliver, R. (2009). *A guide to authentic e-learning*. Routledge.

Holotescu, C. (2015, October). A conceptual model for Open Learning Environments. In *International Conference on Virtual Learning–ICVL* (pp. 54-61).

Howard, J. (2001). Service-learning course design. *Workbook. Michigan, Edward Ginsberg Center for Community Service, The University of Michigan*.

Hoyle, R. H., & Duvall, J. L. (2004). Determining the number of factors in exploratory and confirmatory factor analysis. *Handbook of quantitative methodology for the social sciences*, 301-315.

Huitt, W. (2011). Bloom et al.'s taxonomy of the cognitive domain. *Educational psychology interactive*, *22*.

Hung, D. W., & Wong, A. F. (2000). Activity theory as a framework for project work in learning environments. *Educational Technology*, *40*(2), 33-37.

Institute of Electrical and Electronics Engineers (IEEE), (2001). *Reference Guide for Instructional*

Design and Development. Retrieved January 20, 2022, from https://moam.info/queue/reference-guide-for-instructional-design-and-development_.html

InvariantSpace, (2011). Introduction to the ray model of light. Retrieved from https://www.youtube.com/watch?v=yho7FYmn5vk&ab_channel=InvariantSpace May 22, 2011

Jonassen, D. H., & Rohrer-Murphy, L. (1999). Activity theory as a framework for designing constructivist learning environments. *Educational technology research and development*, *47*(1), 61-79.

Jones, S. K., Noyd, R. K., & Sagendorf, K. S. (2013). *Building A Learning Pathway: An Interactive How-to Guide to Course Design*. AIR FORCE ACADEMY COLORADO SPRINGS CO COLORADO SPRINGS, United States.

Jung, S., & Lee, S. (2011). Exploratory factor analysis for small samples. *Behavior research methods*, *43*(3), 701-709.

Juuti, K., & Lavonen, J. (2012). Design-based research in science education: One step towards methodology. *Nordic studies in science education*, *2*(2), 54-68.

Kain, D., & Wardle, E. (2014). Activity theory: An introduction for the writing classroom. *Wardle and Downs*, 273-283.

Kaltakci, D. E. R. Y. A. (2012). Development and application of a four-tier test to assess pre-service physics teachers' misconceptions about geometrical optics. *Middle East Technical University*.

Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2016). Identifying pre-service physics teachers' misconceptions and conceptual difficulties about geometrical optics. *European Journal of Physics*, *37*(4), 045705.

Kaptelinin, V., Kuutti, K., & Bannon, L. (1995, July). Activity theory: Basic concepts and applications. In *International conference on human-computer interaction* (pp. 189-201). Springer, Berlin, Heidelberg.

Kaptelinin, V., & Nardi, B. (2012). Activity theory in HCI: Fundamentals and reflections. *Synthesis Lectures Human-Centered Informatics*, *5*(1), 1-105.

Kasuga, W. (2019). The influence of politics in curriculum change and innovation in Tanzania. *European Journal of Education Studies*.

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of instructional development*, *10*(3), 2-10.

Kennedy-Clark, S. (2013). Research by Design: Design-Based Research and the Higher Degree Research student. *Journal of Learning Design*, *6*(2), 26-32.

Keser, H., Uzunboylu, H., & Ozdamli, F. (2011). The trends in technology supported collaborative learning studies in 21st century. *World Journal on Educational Technology*, *3*(2), 103-119.

Kettle, M. (2013). Flipped physics. *Physics Education*, *48*(5), 593.

Khandve, P. V. (2016). Interactive teaching and learning activities. In *Proceedings of ISTE the 5th Annual National Convention and International Conference on Challenges and Opportunities in Technical Education in era of Sustainable Development. HVP Mandal's College of Engineering & Technology, India*.

Kim, M. K., Kim, S. M., Khera, O., & Getman, J. (2014). The experience of three flipped classrooms in an urban university: an exploration of design principles. *The Internet and Higher Education*, *22*, 37-50.

Kivunja, C., & Kuyini, A. B. (2017). Understanding and applying research paradigms in educational contexts. *International Journal of higher education*, *6*(5), 26-41.

Knekta, E., Runyon, C., & Eddy, S. (2019). One size doesn’t fit all: Using factor analysis to gather validity evidence when using surveys in your research. *CBE—Life Sciences Education*, *18*(1), rm1.

Knight, R. D. (2008). *Physics for Scientists and Engineers+ Masteringphysics: A Strategic Approach*. Addison-Wesley.

Köse, S. (2008). Diagnosing student misconceptions: Using drawings as a research method. *World Applied Sciences Journal*, *3*(2), 283-293.

Kriek, J., & Grayson, D. (2009). A holistic professional development model for South African physical science teachers. *South African journal of education*, *29*(2), 185-203.

Kruss, G. (ed). (2009) *Opportunities & challenges for teacher education curriculum in South Africa.* (Teacher Education in South Africa Series). Cape Town: HSRC Press.

Kurtz, G., Tsimerman, A., & Steiner-Lavi, O. (2014). The flipped-classroom approach: The answer to future learning. *European Journal of Open, Distance and E-Learning*, *17*(2), 172-182.

Kutbiddinova, R. A., Eromasova, A., & Romanova, M. A. (2016). The Use of Interactive Methods in the Educational Process of the Higher Education Institution. *International Journal of Environmental and Science Education, 11*(14), 6557-6572.

Kuutti, K. (1996). Activity theory as a potential framework for human-computer interaction research. *Context and consciousness: Activity theory and human-computer interaction*, *1744*.

Kyriazos, T. A. (2018). Applied psychometrics: sample size and sample power considerations in factor analysis (EFA, CFA) and SEM in general. *Psychology*, *9*(08), 2207.

Lage, M. J., Platt, G. J., & Treglia, M. (2000). Inverting the classroom: A gateway to creating an inclusive learning environment. *The Journal of Economic Education*, *31*(1), 30-43.

Lee, J., Lim, C., & Kim, H. (2017). Development of an instructional design model for flipped learning in higher education. *Educational Technology Research and Development*, *65*(2), 427-453.

Lincoln, Y. S., Lynham, S. A., & Guba, E. G. (2011). Paradigmatic controversies, contradictions, and emerging confluences, revisited. *The Sage handbook of qualitative research*, *4*(2), 97-128.

Lo, C. K., & Hew, K. F. (2021). Developing a flipped learning approach to support student engagement: A design-based research of secondary school mathematics teaching. *Journal of Computer Assisted Learning*, *37*(1), 142-157.

Lo, C. K., Hew, K. F., & Chen, G. (2017). Toward a set of design principles for mathematics flipped classrooms: A synthesis of research in mathematics education. *Educational Research Review*, *22*, 50-73.

Lo, C. K., & Hew, K. F. (2017). Using "first principles of instruction" to design secondary school mathematics flipped classroom: The findings of two exploratory studies. *Journal of Educational Technology & Society*, *20*(1), 222-236.

Lucariello, J., & Naff, D. (2013). How do I get my students over their alternative conceptions (misconceptions) for learning? Retrieved from http://www.apa.org/education/k12/misconceptions.aspx?item=1

Lundin, M., Bergviken Rensfeldt, A., Hillman, T., Lantz-Andersson, A., & Peterson, L. (2018). Higher education dominance and siloed knowledge: a systematic review of flipped classroom research. *International Journal of Educational Technology in Higher Education*, *15*(1), 1-30.

McTighe, J., & Wiggins, G. (2012). Understanding by design framework. *Alexandria, VA: Association for Supervision and Curriculum Development*.

Mitchell, I., Keast, S., Panizzon, D., & Mitchell, J. (2017). Using 'big ideas' to enhance teaching and student learning. *Teachers and Teaching*, *23*(5), 596-610.

Modisaotsile, B. M. (2012). The failing standard of basic education in South Africa. *Policy brief*, *72*(1).

Manual, D. S. A. T. (2006). Active Learning in Optics and Photonics. *pp (22 to 26).*

Martínez, S. L. D., Lombaerts, K., & Celaya, C. L. (2017). Flipped classroom method as a strategy to promote active learning in physics students at university level. *Latin-American Journal of Physics Education*, *11*(2), 26.

Martinez, S. L. D., Lombaerts, K., & Celaya, C. L. (2017). A compilation of more often used teaching strategies in Physics at University level. *Latin-American Journal of Physics Education*, *11*(2), 24.

Mateus, A. D., Allen-Ile, C., & Iwu, C. G. (2014). Skills shortage in South Africa: Interrogating the repertoire of discussions. *Mediterranean Journal of Social Sciences*, *5*(6), 63-63.

Mathers, N. J., Fox, N. J., & Hunn, A. (1998). *Surveys and questionnaires* (pp. 1-50). NHS Executive, Trent.

Maxwell, J. A. (2016). Expanding the history and range of mixed methods research. *Journal of mixed methods research*, *10*(1), 12-27.

Mazur, E. (1997, March). Peer instruction: Getting students to think in class. In *AIP Conference Proceedings* (Vol. 399, No. 1, pp. 981-988). American Institute of Physics.

Merriam-Webster (n.d). *Merriam-Webster.com dictionary*. Retrieved January 20, 2022, retrieved from https://www.merriam-webster.com/component

Merrill, M. D. (2002). First principles of instruction. *Educational technology research and development*, *50*(3), 43-59.

Merrill, M. D. (2007). First principles of instruction: A synthesis. *Trends and issues in instructional design and technology*, *2*, 62-71.

McGriff, S. J. (2000). Instructional system design (ISD): Using the ADDIE model. *Retrieved June*, *10*(2003), 513-553.

McKimm, J., & Barrow, M. (2009). Curriculum and course design. *British Journal of Hospital Medicine (2005)*, *70*(12), 714-717.

McNeish, D. (2017). Exploratory factor analysis with small samples and missing data. *Journal of personality assessment*, *99*(6), 637-652.

Mji, A., & Makgato, M. (2006). Factors associated with high school learners' poor performance: a spotlight on mathematics and physical science. *South African journal of education*, *26*(2), 253-266.

Nat, M. (2015, April). A flipped classroom model for developing universities in developing countries. In *Global Learn* (pp. 597-604). Association for the Advancement of Computing in Education (AACE).

Network, F. L. (2014). What is flipped learning? The four pillars of FLIP. *Flipped Learning Network*, *501*(2).

Noyd, R. (2010). A primer on writing effective learning-centered course goals. *Washington, DC: Association of American Colleges and Universities.* Retrieved from http://www. designlearning.Org/wp-content/uploads/2010/03/Writing-Good-Learning-Goals.pdf

Nwosisi, C., Ferreira, A., Rosenberg, W., & Walsh, K. (2016). A study of the flipped classroom and its effectiveness in flipping thirty percent of the course content. *International Journal of Information and Education Technology*, *6*(5), 348.

Oberprieler, K., & Leonard, S. N. (2015). A Model for Using Activity Theory in Education Design: A Gamification Example. *Australian Association for Research in Education*.

O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The internet and higher education*, *25,* 85-95.

Ogegbo, A. A., Gaigher, E., & Salagaram, T. (2019). Benefits and challenges of lesson study: A case of teaching Physical Sciences in South Africa. *South African Journal of Education*, *39*(1).

Ornek, F., Robinson, W.R. & Haugan, M.P. (2008). What makes physics difficult? *International journal of environmental & science education, 3 (1)*, 30-34.

Ørngreen, R. (2015). Reflections on Design-Based Research. In *Human Work Interaction Design. Work Analysis and Interaction Design Methods for Pervasive and Smart Workplaces* (pp. 20-38). Springer, Cham.

Ornstein, A. C., & Hunkins, F. P. (2017).*Curriculum foundations, principles and issues* (7th ed.). Pearson Education.

Ozcan, T., Yildirim, O., & Ozgur, S. (2012). Determining of the university freshmen students' misconceptions and alternative conceptions about mitosis and meiosis. *Procedia-Social and Behavioral Sciences, 46*, 3677-3680.

Ozcinar, Z. (2009). The topic of instructional design in research journals: A citation analysis for the years 1980-2008. *Australasian Journal of Educational Technology, 25*(4).

Panadero, E., & Alonso Tapia, J. (2014). How do students self-regulate? review of Zimmerman's cyclical model of self-regulated learning. *Anales de psicologia*.

Pea, R. D., Sipusic, M., & Allen, S. (1990). Seeing the light on optics: Classroom-based research and development of a learning environment for conceptual change. *Development and learning environments. Norwood, NJ: Ablex*.

Pedrotti, L.S. (2008). Basic Physical optics. *Fundamentals of Photonics*, 152-154.

Penny, K. (2011). Factors that influence student e-learning participation in a UK higher education institution. *Interdisciplinary Journal of E-Learning and Learning Objects*, *7*(1), 81-95.

Pett, M. A., Lackey, N. R., & Sullivan, J. J. (2003). *Making sense of factor analysis: The use of factor analysis for instrument development in health care research*. sage.

Phillips, J. A., (2011). *Course design: HPGD 1103 Curriculum development*. Center for Instructional Design and Technology. Open University of Malaysia. https://kupdf.net/download/hpgd1103-curiculum-development_pdf

Plomp, T., & Nieveen, N. (Eds.). (2013). *Educational design research: Part A: An Introduction* (pp.11-50). Enschede, the Netherlands: SLO. https://www.international.slo.nl

Pool, J., Reitsma, G., & van den Berg, D. (2017). Revised community of inquiry framework: Examining learning presence in a blended mode of delivery. *Online Learning*, *21*(3), 153-165 doi: 10.24059/olj.v%vi%i.866

Prediger, S., & Zwetzschler, L. (2013). Topic-specific design research with a focus on learning processes: The case of understanding algebraic equivalence in grade 8. *Educational design research: Illustrative cases*, 407-424.

Randles C., Pasiali V. (2012). Cognitive Psychology of Music Learning. In: Seel N.M. (eds) *Encyclopedia of the Sciences of Learning*. Springer, Boston, MA. https://doi.org/10.1007/978-1-4419-1428-6_1675

Rasool, F., & Botha, C. J. (2011). The nature, extent and effect of skills shortages on skills migration in South Africa. *SA Journal of Human Resource Management*, *9*(1), 1-12.

Reigeluth, C. M., Beatty, B. J., & Myers, R. D. (Eds.). (2016). *Instructional-design theories and models, Volume IV: The learner-centered paradigm of education*. Routledge.

Russell, D. R. (1997). Rethinking genre in school and society: An activity theory analysis. *Written communication*, *14*(4), 504-554.

Şahin, S. (2010). Development and factor analysis of an instrument to measure preservice teachers' perceptions of learning objects. *EURASIA Journal of Mathematics, Science and Technology Education*, *6*(4), 253-261.

Sanders, S. (2019). A Brief Guide to Selecting and Using Pre-Post Assessments. *National Technical Assistance Center for the Education of Neglected or Delinquent Children and Youth (NDTAC)*.

Sands, D. (2014). Concepts and conceptual understanding: What are we talking about? *New Directions in the Teaching of Physical Sciences*, (10), 7-11.

Sankey, M., & Hunt, L. (2014). Flipped university classrooms: Using technology to enable sound pedagogy. *Journal of Cases on Information Technology (JCIT), 16*(2), 26-38.

Sannino, A. E., Daniels, H. E., & Gutiérrez, K. D. (2009). *Learning and expanding with activity theory*. Cambridge University Press.

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. *Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows*, *9*(2), 5-15.

Scholl, K., & Olsen, H. M. (2014). Measuring student learning outcomes using the SALG instrument. *Schole: A Journal of Leisure Studies and Recreation Education*, *29*(1), 37-50.

Schwerdt, G., & Wuppermann, A. C. (2011). Is traditional teaching really all that bad? A within-student between-subject approach. *Economics of Education Review, 30*(2), 365-379.

Schwerdt, G., & Wuppermann, A. C. (2011). Sage on the stage: Is lecturing really all that bad? *Education Next*, *11*(3), 62-67.

Scott, C. L. (2015). Working Papers Preparing Learners For 21st Century Competencies And Skills Overall Vision Of Twenty-First Century Pedagogy Conclusions, Next Steps And Future Issues The Futures Of Learning 3: What Kind Of Pedagogies For The 21st Century.

Seymour, E., Wiese, D., Hunter, A., & Daffinrud, S. (1997). *Student assessment of learning gains (SALG) CAT*. University of Wisconsin-Madison**.** http://archive.wceruw.org/cl1/flag/cat/salg/salg.pdf

Sezer, B. (2017). The effectiveness of a technology-enhanced flipped science classroom. *Journal of Educational Computing Research*, *55*(4), 471-494.

Shah, S.A. (2013). Making the teacher relevant and effective in a technological – led teaching and learning environment. *Procedia-Social and Behavioural Sciences*, 103, 612-620.

Smith, J.K. (2008). Interpretive inquiry. In L.M. Given (Ed.), *The sage encyclopedia of qualitative research methods* (Vol. 1 and 2), p. 488). London: Sage.

Sokoloff, D. R. (2006). Active learning in optics and photonics: training manual. *Zugriff am, 22,* 2018.

Sokoloff, D. R. (2012). Active learning of introductory optics: Strategies for the US and the developing World. Latin-American *Journal of Physics Education*, *1*(16), 6.

Sokoloff, D. R. (2017). Enhancing learning in lab and lecture with real time physics labs (RTP) and interactive lecture demonstrations (ILDs) using computer-based data acquisition tools, personal response systems (clickers) and interactive video analysis. *Physics Teachers' Inventions Fair*, 3-4.

Srisawasdi, N. (2012). The role of TPACK in physics classroom: case studies of preservice physics teachers. *Procedia-Social and Behavioural Sciences*,46, 3235 – 3243.

Stemberger, T., & Cencic, M. (2014). Design-based research in an educational research context. *Sodobna Pedagogika*, *65*(1), 62.

Tabachnick, B. G., & Fidell, L. S. (2013). Using multivariate statistics: International edition. *Pearson2012*.https://www.pearson.com/uk/educators/higher-education-educators/program/Tabachnick-Using-Multivariate-Statistics-International-Edition-6th-Edition/PGM10378

Taherdoost, H. (2016). Validity and reliability of the research instrument; how to test the validation of a questionnaire/survey in a research. *How to test the validation of a questionnaire/survey in a research (August 10, 2016)*.

Taherdoost, H. A. M. E. D., Sahibuddin, S. H. A. M. S. U. L., & Jalaliyoon, N. E. D. A. (2014). *Exploratory factor analysis; concepts and theory*. HAL.

Talyzina, N. F. (1981). *The psychology of learning: Theories of learning and programmed instruction*. Progress Publishers.

Taslidere, E., & Eryilmaz, A. (2015). Assessment of pre-service teachers' misconceptions in geometrical optics via a three-tier misconception. *Journal of Faculty of Education, 4*(1), 269-289.

Thapa, D., & Lakshminarayanan, V. (2013, July). Light & optics conceptual evaluation findings from first year optometry students. In *Education and Training in Optics and*

Photonics (p. EThI3). Optical Society of America.

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., ... & Depaepe, F. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education*, *3*(1), 2.

Thijs, G. D., & Van Den Berg, E. D. (1995). Cultural factors in the origin and remediation of alternative conceptions in physics. *Science & Education*, *4*(4), 317-347.

Thompson, B. (2004). Exploratory and confirmatory factor analysis: Understanding concepts and applications. *Washington, DC, 10694*.

Thompson, B., & Daniel, L. G. (1996). Factor analytic evidence for the construct validity of scores: A historical overview and some guidelines.

Tichapondwa, S. M. (Ed.). (2013). *Preparing your dissertation at a distance: A research guide*. Virtual University for small States of the Commonwealth.

Tularam, G. A. (2018). Traditional vs Non-traditional Teaching and Learning Strategies-the case of E-learning. *International Journal for Mathematics Teaching and Learning*, *19*(1), 129-158.

Tural, G. (2015). Cross-Grade Comparison of Students' Conceptual Understanding with Lenses in Geometric Optics. *Science Education International*, *26*(3), 325-343.

Tyler, R. W. (2013). *Basic principles of curriculum and instruction*. University of Chicago press.

Uchinokura, S. (2018). Students’ use of representation and particle models for dissolution. In *ESERA 2017 Conference* (pp. 400-411).

Uzunboylu, H., & Karagözlü, D. (2017). The emerging trend of the flipped classroom: A content analysis of published articles between 2010 and 2015. *Revista de Educación a Distancia (RED)*, (54).

Vakili, M. M. (2018). Assessment of construct validity questionnaires in psychological, educational and Health research: Applications, Methods, and Interpretation of Exploratory factor analysis. *Journal of Medical Education Development*, *11*(30), 4-19.

Walvoord, B. E., & Anderson, V. J. (2011). *Effective grading: A tool for learning and assessment in college*. John Wiley & Sons.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational technology research and development*, *53*(4), 5-23.

Whitehouse, M. (2014). Using a backward design approach to embed assessment in teaching. *School Science Review, 95*(352), 99-104.

Williams, B., Onsman, A., & Brown, T. (2010). Exploratory factor analysis: A five-step guide for novices. *Australasian journal of paramedicine*, *8*(3).

Wilson, T. D. (2006). A Re-Examination of Information Seeking Behaviour in the Context of Activity Theory. *Information research: an international electronic journal*, *11*(4), n4.

Wilson, S. M., & Peterson, P. L. (2006). Theories of Learning and Teaching: What Do They Mean for Educators? Working Paper. *National Education Association Research Department*.

Youell, A. (2011). *What is a course or programme or route or pathway or learning opportunity*? Higher Education Statics Agency. https://www.hesa.ac.uk/files/What-is-a-course_2011.pdf

Yung-kuo, L. (1991). *Problems and Solutions on Optics*. Singapore, World Scientific Publishing *Co.* pte. Ltd

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: Anoverview. *Educational psychologist*, *25*(1), 3-17.

Zurita, G., & Nussbaum, M. (2007). A conceptual framework based on activity theory for mobile CSCL. *British Journal of Educational Technology*, *38*(2), 211-235.

APPENDICES

APPENDIX A

Syllabus of the B.Ed. Programme - Physics component

<table>
<tr><td>Topic</td><td>Outcomes & Assessment Criteria</td></tr>
<tr><td>UNIT 1

<u>RAY MODEL OF LIGHT</u>

Unit goal:
To demonstrate knowledge and understanding of the ray model concept of light

The concept of light
Models of light</td><td>Students should understand the ray model concept of light, so they can:
Define a ray as an idealization meant to represent an infinitely narrow beam of light
Distinguish between light rays and light waves through the conditions under which the different models of light are applicable
Use ray model assumptions to explain behavior of light across interfaces and formation of images in both familiar and unfamiliar contexts
Use the ray model of light to explain how we see things that are not sources of light and how shadows are formed</td></tr>
<tr><td>UNIT 2

<u>REFRACTION OF LIGHT</u>

Unit goal
To demonstrate knowledge and understanding of refraction of light

Refraction of light
Speed of light
The law of refraction
Total internal reflection
Lenses
Images formed by refraction</td><td>Students should understand the principle of refraction so they can:
Predict the path changes of light across boundaries between transparent mediums at non-normal and normal angles resulting from change of speed
Illustrate qualitatively and quantitatively how the speed and wavelength of light change when light passes from one medium into another
Explain the phenomenon of total internal reflection in different material mediums
Solve problems involving Snell’s law in both familiar and unfamiliar contexts
Use the rules for ray tracing and the sign convention to quantitatively determine the location and nature of an image formed by refraction involving thin lenses and thick (spherical) lenses.
Illustrate the formation of images using the technique of ray tracing
Determine the power of a lens in both familiar and unfamiliar contexts</td></tr>
<tr><td>UNIT 3

<u>REFLECTION OF LIGHT</u>

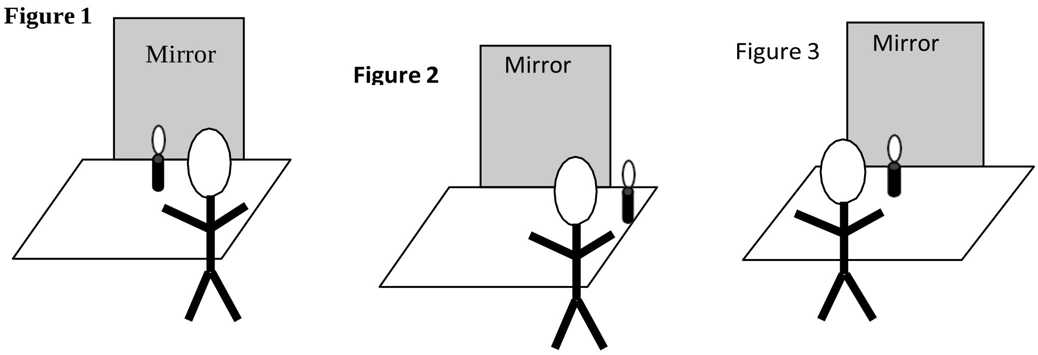
Unit goal
To demonstrate knowledge and understanding of the reflection of light
Reflection of light
The law of reflection
The plane mirror
The spherical mirror
Images formed by reflection of light</td><td>Students should understand the principle of reflection, so they can:
Explain reflection of light from polished and rough surfaces
Illustrate image formation in flat mirror and spherical mirror using graphical methods (ray tracing techniques)
Explain with ray diagrams the formation of an image using plane and spherical mirror
Use algebraic and graphical methods for analyzing image formation in plane and spherical mirrors
Use algebraic methods to solve problems involving plane and spherical mirrors in both familiar and unfamiliar contexts</td></tr>
</table>

APPENDIX B

Light and Optics Conceptual Evaluation (LOCE) Test

DIRECTIONS: Answer questions 1-43 on the answer sheet by writing in the letter corresponding to the best choice. Also include brief written answers for Questions 28, 30, 31, and 34, and sketch your answer for Question 43, all on the answer sheet.

Questions 1-5 refer to the three figures below of a candle on a table in front of a plane (flat) mirror.



1. In Figure 1, a person is standing in front of the table looking into the mirror. The image of the candle is located

   A. In front of the mirror,
   B. On the surface of the mirror,
   C. Behind the mirror,
   D. There is no image of the candle,
   E. Not enough information is given.

2. The height of the image of the candle is

   A. Larger than the candle,
   B. Smaller than the candle,
   C. The same size as the candle,
   D. There is no image of the candle,
   E. Not enough information is given.

3. In Figure 2, the candle is moved to the new location shown. The image of the candle as seen by the person is now

   A. To the left of where it was before,
   B. To the right of where it was before,
   C. In the same location as before,
   D. No image is seen by the person,
   E. Not enough information is given.

4. In Figure 3, the candle is moved back to its original location, and the person moves to the left to the new position shown. Compared to Figure 1, the location of the image of the candle is now

A. To the left of where it was in Figure 1,
B. To the right of where it was in Figure 1,
C. In the same location as in Figure 1,
D. There is no image of the candle,
E. Not enough information is given.

5. The distance of the candle from the mirror is doubled. The height of the image of the candle is now

   A. Smaller than before,
   B. The same size as before,
   C. Larger than before,
   D. There is no image of the candle,
   E. Not enough information is given.

Questions 6-10 refer to a very narrow beam of light (for example, a laser beam) that can be represented by a single ray. The light is initially traveling from left to right in a transparent medium of index of refraction n_1, and incident on a second transparent medium of index of refraction n_2. The reflected and refracted rays are as shown in the diagrams below. (If either is missing, it means there is no reflected or no refracted ray.) Answer each of the questions below with one of the following choices, **A** through **F**.

A. Only if $n_2 > n_1$,

B. Only if $n_2 = n_1$,

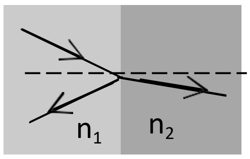
C. Only if $n_2 < n_1$,

D. Can happen with A or C.

E. Never possible.

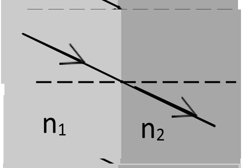
F. Always possible regardless of the relative sizes of the indexes of refraction.

6. For which condition **A** through **F** could the rays be as shown in the figure?

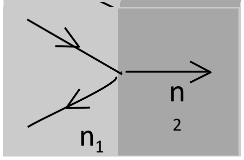


7. For which condition **A** through **F** could the rays be as shown in the figure?

8. For which condition **A** through **F** could the rays be as shown in the figure?

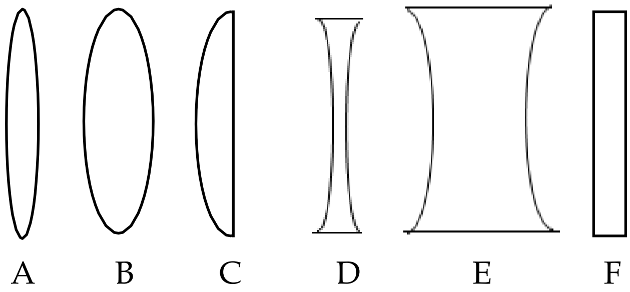


9. For which condition **A** through **F** could the rays be as shown in the figure?



10. For which condition **A** through **F** could the rays be as shown in the figure

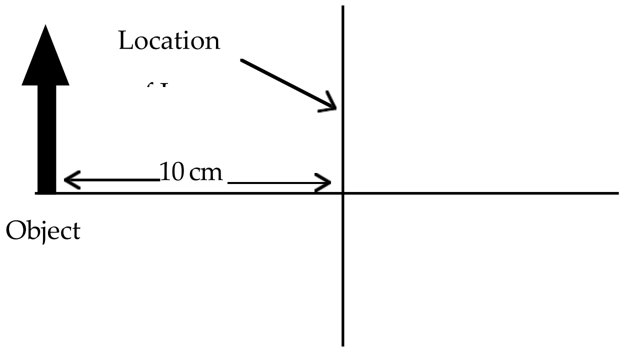
Questions 11-17 refer to the six lenses **A - F** shown on the right. All of the lenses are made of the same glass. Choose the lens that best answers each question below. There is only one correct answer for each question. If you think that none of the lenses is correct, choose answer **G**.



11. Which lens has the shortest positive focal length?
12. Light from the sun is focused by the lens to form a sharp spot on a piece of paper. Which lens must be held closest to the paper?
13. Which lens has the shortest negative focal length?
14. Which lens used as a magnifier would produce the largest magnification?
15. Which lens would give the largest correction to a person who is nearsighted? (Nearsighted people have distant objects focused in front of their retina. They can clearly see objects that are close to their eyes, but objects far away are blurred.)
16. Which lens has no focusing effect on light incident upon it?
17. Which lens would give the largest correction to a person who is farsighted? (Farsighted people have close objects focused behind their retina. They can clearly see objects that are far away from to their eyes, but objects that are close are blurred.)

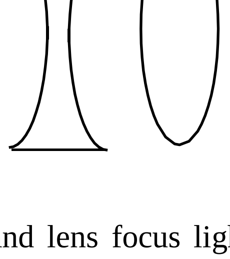
Questions 18-22 refer to an object that is positioned 10 cm in front of a lens. The lens is either shaped like lenses 1 or 2 shown below.

For each of the possible lenses in Questions 18- 22, choose the one statement **A - D** that correctly describes the image formed by that lens. If none of the descriptions is correct, choose answer **E**.



A. The image is upright and larger than the object.
B. The image is upright and smaller than the object.
C. The image is inverted and larger than the object.
D. The image is inverted and smaller than the object.
E. None of the descriptions of the lens is correct.

18. The lens looks like 1 with focal length 4 cm.
19. The lens looks like 2 with focal length 8 cm.
20. The lens looks like 2 with focal length 16 cm.
21. The lens looks like 2 with focal length 4 cm.
22. The lens looks like 1 with focal length 16 cm.



23. For a person with myopia (nearsightedness) the cornea and lens focus light from

distant objects in front of the retina, causing blurred vision of distant objects. To correct myopia, the person should wear glasses (spectacles) with lenses that have which of the following prescriptions?

A. A spherical lens with positive power,

B. A spherical lens with negative power,

C. A cylindrical lens with positive power,

D. A cylindrical lens with negative power,

E. A combination of spherical and cylindrical lenses,

F. None of the above.

24. For a person with hyperopia (farsightedness) the cornea and lens focus light from near objects behind the retina, causing blurred vision of near objects. To correct hyperopia, the person should wear glasses (spectacles) with lenses that have which of the following prescriptions?

A. A spherical lens with positive power,

B. A spherical lens with negative power,

C. A cylindrical lens with positive power,

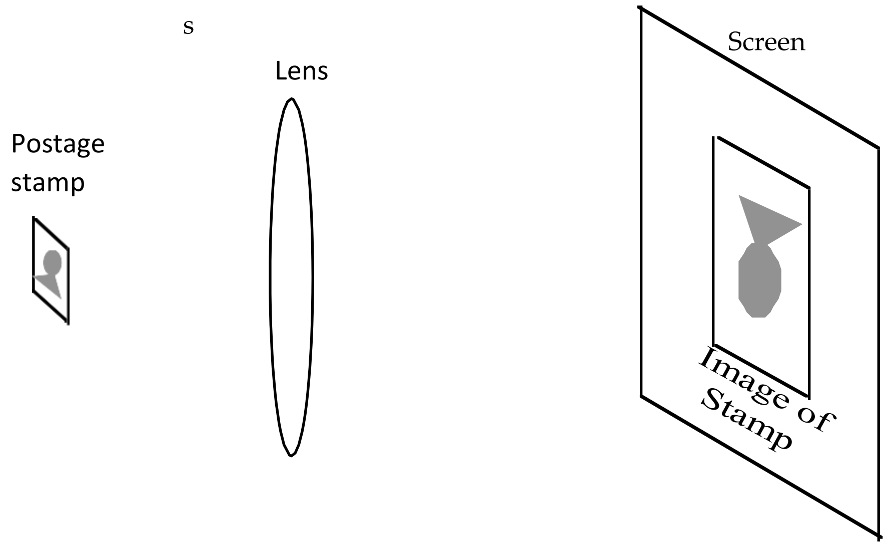
D. A cylindrical lens with negative power,

E. A combination of spherical and cylindrical lenses,

F. None of the above.

Questions 25-34 refer to the picture on the right. A stamp is placed to the left of the lens, and its image is formed on a screen to the right of the lens, as shown.

Choose the correct answer for each question.



25. Suppose the stamp is temporarily replaced (only for this question) with one twice as large. Which is true?

A. The image will be whole but half as large,
B. The image will disappear,
C. The image will be dimmer,
D. Only half of the image will be seen,
E. The image will be twice as large,
F. The image will be unchanged,
G. None of these is correct.

26. Suppose the lens is temporarily replaced (only for this question) by a lens with half the diameter but with the same focal length. Which is true?

A. Half of the image will disappear,
B. The image will be whole but half as large,
C. The image will disappear,
D. The image will be dimmer,
E. The image will be unchanged,
F. None of these is correct.

27. Suppose that the screen is temporarily moved further away (only for this question) with the positions of the stamp and lens unchanged. Which is true?

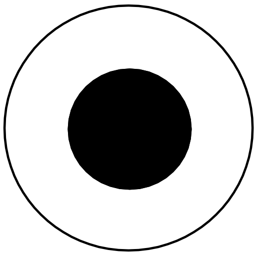
A. The image will be blurry,
B. The image will be sharp but slightly larger,
C. The image will be sharp but slightly smaller,
D. The image will be unchanged,
E. The image will disappear,
F. None of these is correct.

28. Suppose the top half of the lens is temporarily covered by a piece of paper (only for this question) so that no light can pass through this portion. Which is true?

A. Half of the image will disappear,
B. The image will be whole but half as large,
C. The image will disappear,
D. The image will be dimmer,
E. The image will appear on the paper,
F. The image will be unchanged,
G. None of these is correct.

Briefly explain your answer:

29. Suppose a circular piece of black tape temporarily covers the center of the lens (only for this question) as shown on the right. Which is true?



A. The center of the image will disappear,
B. The image will be whole but smaller,
C. The image will disappear,
D. The image will be dimmer,
E. The image will appear on the tape,
F. The image will be unchanged,
G. None of these is correct.

30. Suppose half of the stamp is temporarily covered by a piece of paper (only for this question). What happens to the image of the stamp?

A. Half of the image will disappear,
B. The image will be whole but half as large,
C. The image will disappear,
D. The image will be dimmer,
E. The image will appear on the paper,
F. The image will be unchanged,
G. None of these is correct.

Briefly explain your answer:

31. Suppose that the stamp is temporarily moved slightly further away from the lens (only for this question). The screen is also moved to find the sharpest possible image. Which is true?

A. The image is now larger than before,
B. The image is now upright,
C. The image is now the same size as before,
D. The image is now smaller than before,
E. None of these is correct.

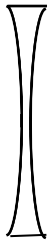
Briefly explain your answer:

32. Suppose that the stamp is temporarily moved closer to the lens (only for this question). The screen is also moved to find the sharpest possible image. Which is true?

A. The image is now smaller than before,
B. The image is now the same size as before,
C. If the object is moved close enough to the lens, it is possible that no sharp image will be found on the screen,
D. The image on the screen will become upright,

E. None of these is correct.

33. Suppose that the lens is temporarily replaced by one that looks like the one on the right (only for this question). The screen is moved to find the sharpest possible image. Which is true?



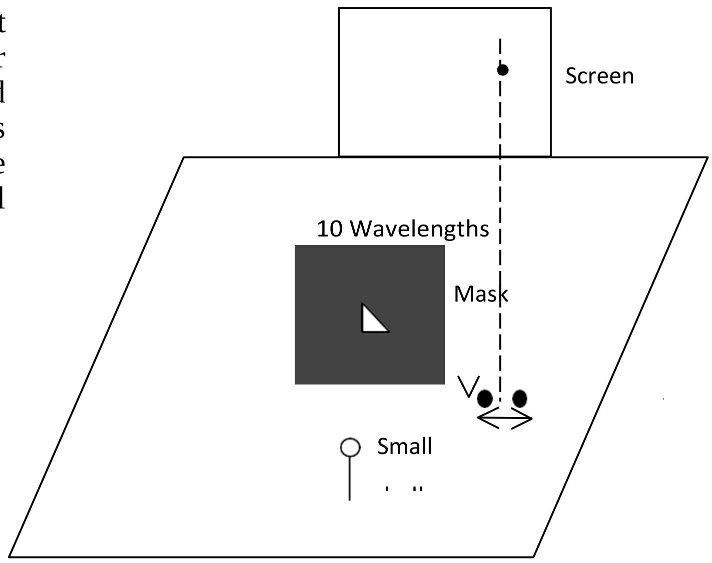
A. The image will be larger,
B. The image will be the same size,
C. The image will be smaller,
D. It will not be possible to find a sharp image on the screen,
E. The image will be upright,
F. None of these is correct.

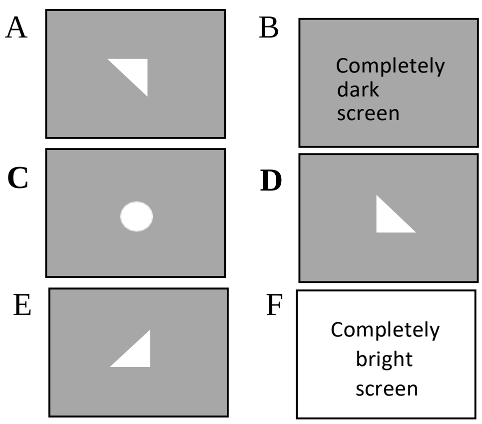
34. Suppose the lens is removed. Which is true?

A. The image will still be there but a little blurred,
B. The image will be whole but smaller,
C. The image will disappear,
D. The image will be dimmer,
E. The image will be unchanged,
F. None of these is correct.

Briefly explain your answer:

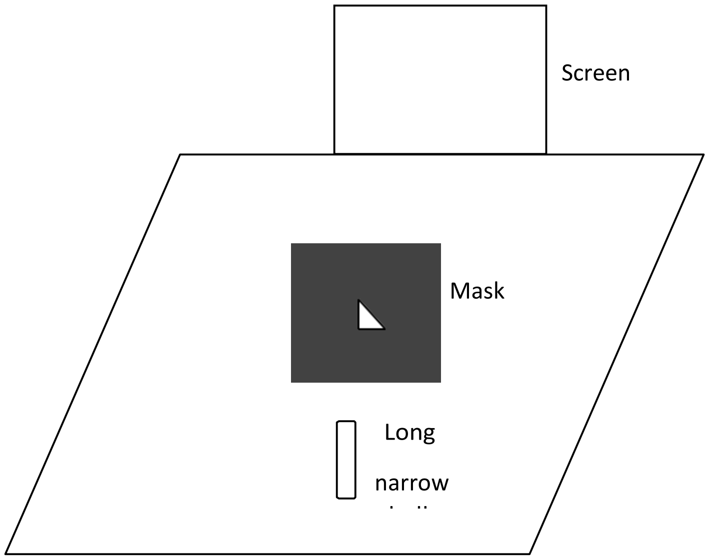
35. A very small light bulb is held in front of a screen. A mask with a triangular hole larger than the bulb is placed between the bulb and the screen as shown on the right. Which picture below correctly shows what will appear on the screen?

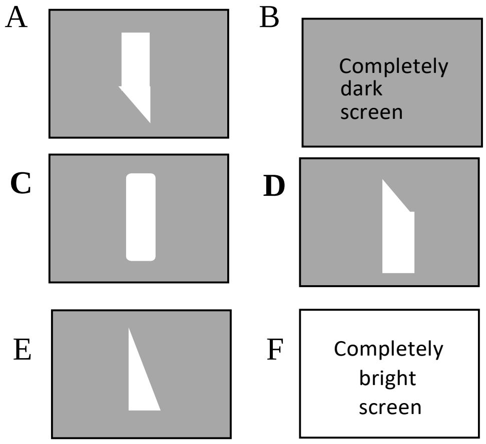




G. None of the above is correct.

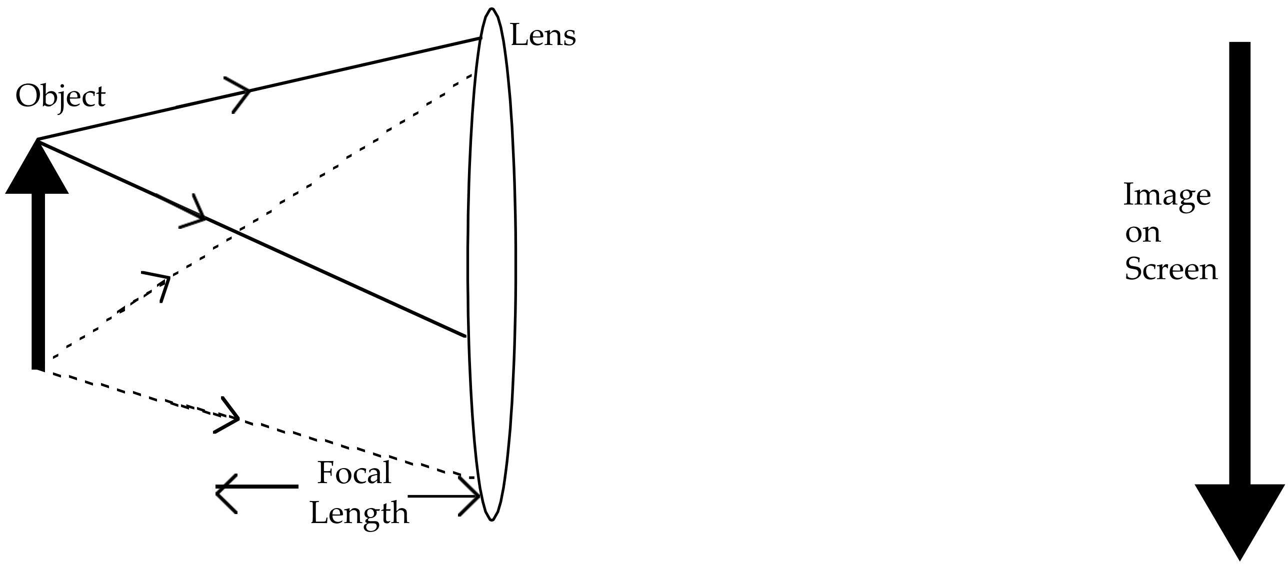
36. The bulb in (41) is replaced by a long, narrow bulb. Which picture below correctly shows what will appear on the screen?





G. None of the above is correct.

37. In the picture below, the object is to the left of the lens, at a distance from the lens that is larger than the focal length. The image is formed on a screen to the right of the lens as shown. Four rays of light are shown leaving points on the object. Continue those four rays through the lens to the screen.



Light and Optics Test Answer Sheet

Name____Class__________________________

_____1.	_____7.	_____13.	_____19.	_____25.	_____31.	_____37.	_____43.	_____49.
_____2.	_____8.	_____14.	_____20.	_____26.	_____32.	_____38.	_____44.	_____50.
_____3.	_____9.	_____15.	_____21.	_____27.	_____33.	_____39.	_____45.	
_____4.	_____10.	_____16.	_____22.	_____28.	_____34.	_____40.	_____46.	
_____5.	_____11.	_____17.	_____23.	_____29.	_____35.	_____41.	_____47.	
_____6.	_____12.	_____18.	_____24.	_____30.	_____36.	_____42.	_____48.	

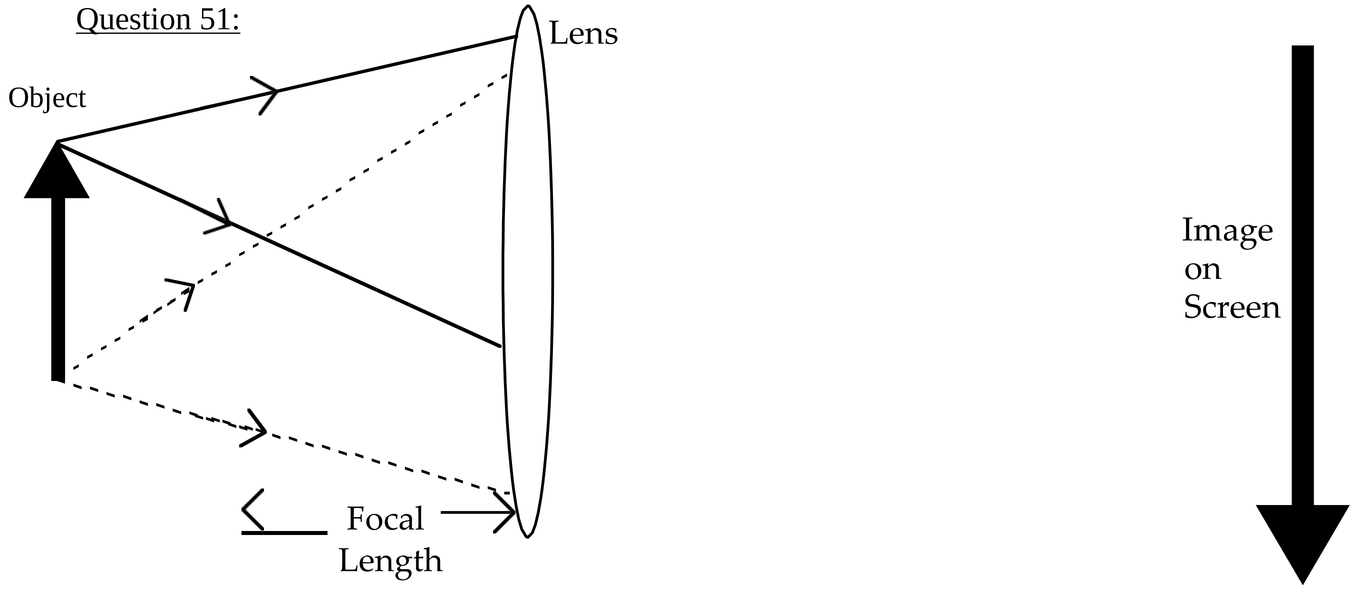
Briefly explain your answer to Question 28:

Briefly explain your answer to Question 30:

Briefly explain your answer to Question 31:

Briefly explain your answer to Question 34:

Question 51:



APPENDIX C
Ethical Clearance Certificate

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 2212, Fax: (015) 268 2306, Email:noko.monene@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE CLEARANCE CERTIFICATE

MEETING: **03 March 2017**

PROJECT NUMBER: **TREC/26/2017: IR**

PROJECT:

Title:	Flipped classroom model: Pre-service teachers' learning experience in a geometric optics course
Researcher:	Mr VN Dhamu
Supervisor:	Prof J Kriek
Co-Supervisor:	N/A
Institution:	University of South Africa
Research:	Independent

PROF TAB MASHEGO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:
i) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee.**
ii) **The budget for the research will be considered separately from the protocol.**
PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.

Finding solutions for Africa

APPENDIX D

Gatekeeper permission to conduct research

University of Limpopo
Office of the Registrar
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 2407, Fax: (015) 268 3048, Email: Office.Registrar@ul.ac.za

17 May 2017

Mr. VN Dhamu

Email: Nesbert.Dhamu@ul.ac.za

Dear Mr. Dhamu,

GATEKEEPER PERMISSION TO CONDUCT RESEARCH

TITLE: FLIPPED CLASSROOM MODEL: PRE-SERVICE TEACHERS' LEARNING EXPERIENCE IN A GEOMETRIC OPTICS COURSE

SUPERVISOR: **Prof. J Kriek**
INSTITUTION: **University of South Africa**
RESEARCH: **Independent research**

Kindly be informed that Gatekeeper permission is granted to you to conduct research at the University of Limpopo entitled: **"Flipped classroom model: pre-service teachers' learning experience in a geometric optics course".**

Kind regards,

DR. JEFFREY MABELEBELE
UNIVERSITY REGISTRAR

Cc. Prof. RN Madadzhe, Acting Deputy Vice-Chancellor: Teaching and Learning
Mr. T Mabila, Acting Director: Research Development and Administration
Prof. TAB Mashego – Chairperson: Research and Ethics Committee
Ms. N Monene – Office Manager: Research Development and Administration

Finding solutions for Africa

APPENDIX E
Consent form

TURFLOOP RESEARCH ETHICS COMMITTEE

PART IV

CONSENT FORM

PROJECT TITLE: *Flipped classroom model: pre-service teachers' learning experience in a geometric optics course.*

PROJECT LEADER/SUPERVISOR: *Jean Kriek*

I,____hereby voluntarily consent to participate in the following project: *Flipped classroom model: pre-service teachers' learning experience in a geometric course.*

I realise that:

1. This study deals with *the effect of an instructional model on students' level of understanding in a physics component of a physical science course.*

2. My participation in this study is voluntary. The process may hold some risk for me that cannot be foreseen at this stage. Therefore any new information that may become available during the research process that may influence my willingness to continue my participation shall be brought to my attention. I may withdraw and discontinue at any time without penalty, whether or not I feel discomfort.

3. This research study, where individuals may be approached to participate in the study, has been reviewed and approved by the Ethics Committee.

4. The overall goal, procedure, and benefits of the research have been explained to me.

5. The study sets out the risks that can be reasonably expected as well as possible discomfort for persons participating in the research.

6. Any information in connection with this study that can be identified with me will remain confidential, with access restricted to persons directly involved in the research, and will be disclosed only with my permission or as required by law.

7. The researcher/s will address any questions that I may have regarding the research, or related matters.

8. If I have any questions about, or problems regarding the study, or experience any undesirable effects, I may contact a member of the research team or Ms Noko Shai-Ragoboya.

9. If any medical problem is identified at any stage during the research, or when I am

APPENDIX F

Assessing Student Learning Gains (SALG)

Module Name ___________________________________Year ___________________

Please take some time (approximately 60 minutes) to complete this questionnaire. Your responses will provide important information that will help to improve in planning better ways to support your learning.

Purpose of the survey

This survey provides you with an opportunity to share your thoughts on how to improve the method of lesson delivery in physics.

A new method of delivery was namely:

1. VIDEO WATCHING
    - Students watch videos posted on the blackboard before coming for their lecture period
    - Read all the recommended readings

2. VIDEO ASSESSMENT
    - A short quiz is given to students that summarises the key ideas in the video previously watched

3. CLASS ACTIVITIES

Students carry out the following activities:

- Organise themselves into a small collaborative workgroup (5 members)
- Students are provided with exercises to complete through group discussion
- Complete all of the exercises provided with clear and precise diagrams

You do not have to complete this survey if you do not wish to do so. However, everyone's views are important, bearing in mind that future students will benefit from your contributions which will be used to improve this instructional approach. The questionnaire is completely confidential. *Please respond honestly*: **Do Not** write your name on the questionnaire.

Gender: (*please put **a cross** in the appropriate box*)

Male		Female	

Age: (*please put **a cross** in the appropriate box*)

Under 18	
18-19	
20-21	
22-24	
25 and above	

A. Module content

As a result of the method stated above for content delivery used in this module, how well do you think that you now understand each of the following?

	Not at All	A Little	Moderate	A Lot	A Great Deal
A1. Stating and Using the key ideas outlined in the ray model of light					
A2. Distinguishing between ray and wave models of light					
A3. Distinguishing between mirror and diffuse reflections					
A4. Using Snell's law to predict the path of a light ray as it moves from one medium into another					
A5. Using the ray tracing method to locate the image position for an object placed a specified distance from a mirror					
A6. Using the ray tracing method to locate the image position for an object placed a specified distance from a lens					
A7. Distinguishing between the roles played by the mirror, lens and screen in image formation					
A8. Using the mirror equation and sign convention to determine the position, magnification and size of the image formed by a mirror					
A9. Using the lens equation and sign convention to determine the position, magnification and size of the image formed by the lens					
A10. Deducing the law of refraction and reflection using Fermat's principle					
A11. Describing the operation of optical fibres using total internal reflection					
A12. Describing what happens to speed, frequency and wavelength when light goes from one medium to another					

A13. Applying the ray model, geometrical laws and principles in solving problems					

Any other comments:

____

B. Instructional approach

How much did each of the following aspects of the instructional approach help you understand the content?

	Did not help	Helped a Little	Moderate Help	Helped Much	Helped a Lot
B1. Participating in discussions during class					
B2. Listening to discussions during class					
B3. Participating in group work during class					
B4. The order of priority used to discuss main ideas of the topic: 1-*photon, wave, & ray models*. 2-*refraction & laws of refraction*. 3-l*enses & ray diagrams*. 4-*reflection and laws of reflection*. 5-*total internal reflection*. 6-*mirrors & ray diagrams*					
B5. The feedback received from the instructor on questions posed during class discussions of content					
B6. The feedback on my work received after tests.					
B7. Video presentations posted on blackboard by the instructor					
B8. The level of difficulty of the problems discussed in class					
B9. Presentations by group representatives after discussion of problems in respective groups					
B10. Pre-laboratory design activities					
B11. Laboratory practical activities					
B12. The quiz written after watching each video presentation					
B13. Reading material recommended by the instructor					
B14. The level of difficulty of written tests					

Any suggestions to improving the way this module was taught? Please comment in the space provided

____
____
____

C. Attitude towards the module

As a result of the approach used to teach and learn this module, what ***gain*** *did you make on the following*?

	Not at All	A Little	Moderate	A lot	A Great Deal
C1. Your interest to learn more of geometrical optics					
C2. Enthusiasm for the subject of physics					
C3. Feeling at ease when working with complex problems in geometrical optics					
C4. Your willingness to seek help from others when working on academic problems					
C5. Confidence that you understand geometrical optics					
C6. Your confidence to write the final examination					
C7. In the way this module has been taught compared to the way your previous physics module was taught					

Any other comments you might wish to add:

____
____
____
____

APPENDIX G

Sample of responses to open-ended questions

Students were asked to write ANY OTHER COMMENTS they might have had after completing 13 closed items about the MODULE CONTENT.	
Student ID	Coded Comments
1	No comment
2	No comment
3	Fermat’s principle is what we have not discussed, and I have heard a bit about in some of my videos it sounds very important. Content-NS
4	No comment
5	No comment
6	No comment
7	No comment
8	No comment
9	No comment
10	The content was well presented and was very clear to everyone. Keep the good work. You did the best for us. Let’s hope you will continue doing the same. Content-PS
11	No comment
12	Assessment should not always take place in order to allow student to learn and discover learning. Assessment-NS
13	No comment
14	No comment
15	Explain to us the video we have watched is saying in order to clarify where we didn’t understand before you give quiz or work to do. Video-R
16	No comment
17	No comment
18	No comment
19	No comment
20	No comment
21	More practical work and integration of feedbacks. Content-R/Feedback-R
22	The method of video watching was good and clear to understand and time serving. Video-PS
23	No comment
24	No comment
25	I’m satisfied with how the content is delivered in comparison this year is better than last. Instruction-PS
26	The videos were of good help to me, I think they must be used in the future lessons. Video-PS
27	No comment
28	No comment
29	No comment

30	The lecturer best presented his lessons in such a way that we all came to the point where we understood and implemented the knowledge by showing better and greater performance. Lecturer-PS
31	No comment
32	I prefer the videos other than the lectures. Video-PS
33	More material should be provided having examples of how the problems can be solved using the appropriate principle. Video-R
34	The videos presented by the lecturer, I think they should include problem solving, at least one difficult one. But by the way everything is okay. Video-R
35	No comment
36	No comment
37	The videos I prefer them most unlike classroom lessons. I learn best by observing. Video-PS
38	I think the use of videos is very effective because we have the ability and time to play them over and over again to enhance our understanding. Video-PS
39	No comment
40	No comment
41	No comment
42	No comment
43	The way the module is presented is very good and again it gives an opportunity to revisit if not properly understood. Instruction-PS
44	No comment
45	No comment
46	I think the video method is working more than the other method because we can recall what was on the video more than reading a book. Video-PS
47	No comment
48	You should bring complex problem-solving questions when giving us videos. Video-R
49	No comment
50	Work on videos which talks about index of refraction and also the ones which proves the laws because I am still struggling with index of refraction calculations but not Snell's laws. Video-R
51	No comment
52	First three videos they didn't maintain my attention. I was losing concentration but last videos they were good. Video-PS
53	No comment
54	No comments. Everything was clearly outlined. Instruction-PS
55	The videos were helpful, and I have learnt enough from it. Video-PS
56	The content is understandable. The videos given to us are helpful since they give us the pictures of what we have learnt. Video-PS
57	When teaching using videos, students learn more because if the concept explained in the video, they don't get it correct they can repeat it several times. Videos-PS
58	The thing about a ray model is that in the videos they take it from refraction

	laws which makes it difficult to relate while they use water waves in diffraction and light in ray model. Content-NS
59	I so wish that in the coming semester you could use this method. That's my plea. I have enjoyed and gain knowledge. Instruction-R
60	No comment
61	The lectures were excellent. Instruction-PS
62	No comment
63	No comment
64	This teaching strategy is way too good. Best when you use your own recorded videos. Instruction-PS
65	No comment
66	This lecturer is really passionate, and he is the right man to prepare teachers. I wish all lecturers were like him. Lecturer-PS
67	No comment
68	Sign convention is a topic I am still struggling because it confuses me. Content-NS
69	No comment
70	No comment
71	This overall method that is been used is too beneficial to most of the students. We were able to obtain better grades because of the method. I encourage the lecturer to continue using this method since we learn in different learning styles. The video also accommodate 95% of the students in the classroom. Instruction-PS
72	No comment
73	No comment
74	No comment
75	No comment
76	No comment
77	No comment
78	Keep the method of teaching up and use it also in the next semester. Instruction-PS
79	No comment
80	Lesson facilitation is more interesting when teaching in contact. Then he should consider in teaching in contact more often for understanding. Class discussion-PS
81	No comment
82	No comment
83	No comment
84	No comment
85	The module has been facilitated well, but the problem is one: giving us a lot of work to do that is to be submitted though it is not contributing towards our semester marks. This give us a lot of pressure and make us loose concentration. Post class activity-NS
86	No comment
87	Sign convention were a bit cumbersome. Content-NS

88	No comment
89	Videos are much more helpful because we can replay them to get more understanding. Video-PS
90	No comment
91	Keep up the good work. Lecturer-PS
92	No comment
93	No comment
94	The work that you provided to us was relevant to what you are going to assess to us in quiz test … don't know about the exam. Assessment-PS
95	No comment
96	As we get a lot of work to do, it enables us to practice. This was a great idea so far because in class we discuss activities and also the difficulties that we have. Class discussion-PS
97	No comment
98	Reduce workload for students. It increases pressure. Post class activity R
99	On class discussion we should be presenting our ideas for that comments and briefly give valid reasons scholarly. Class discussions R
100	No comment
101	No comment
102	No comment
103	No comment
104	It seems to be a very powerful method of teaching and it is that helpful for us as students of HPHA031. Instruction-PS
105	No comment
106	The videos are very helpful because we can also watch them when we are away on our teaching practice. Video-PS
107	No comment
108	The delivering of teaching content was fine. Just it was like we were doing only physics since a lot of work was given in a limited space of time. Post class activity-NS
109	No comment
110	No comment
111	No comment
112	No comment
113	No comment
114	No comment
115	The content of the module I understand it a little bit because I did not do it in Matric. Content-NS
116	The videos clearly shows the deductions of formulae explanation and sign convention, but examples given in class some he didn't further explain. Content-NS
117	No comment
118	No comment
119	More videos will be helpful otherwise everything is in position students understand well better than reading theory. Video-PS

120	No comment
121	The videos are really helpful for some of us who really don’t get the explanation in class but on videos we can watch again and again to gain more understanding. Video-PS
122	No comment
123	I think I know most of the things, all thanks to the lecturer because of the videos, they helped me a lot. Video-PS
Any suggestions to improving the way this module was taught? Please comment in the spaces provided.	
Student ID	Coded comments
1	No comment
2	No comment
3	No comment
4	No comment
5	No comment
6	The module this year was taught very well, everything was going very well, going to class was very, very helpful a lot because we were gaining something in class. I enjoyed a lot being with the lecturer. Lecturer-PS
7	The level of difficulty of questions is very high and so challenging. Please try to reduce to accommodate some of us. Assessment-NS
8	Instructor you have to give us two tests, one must be not difficult and one too difficult, not always a difficult test. Assessment-R
9	No comment
10	No comment
11	No comment
12	Assessment should not always take place. Assessment-R
13	Use video. Be each on every lesson, because it’s understandable and recallable after seeing it. Video-R
14	No comment
15	Clear explanation must be given to learners after they have watched the video, remember we can watch but we can’t ask where we don’t understand. Video-R
16	Provide student scripts in order for them to see where they went wrong. Feedback-R
17	Give us more activities to work on, the type of questions that can sharpen our understanding. Post class activity R
18	No comment
19	No comment
20	No comment
21	Clear and proper feedback from the instructor is requested. Feedback-R
22	The quiz before the lesson starts really helped me. Because everything before I attend, I make sure that I prepare before going to the class. Assessment-PS
23	No comment

24	Everything was on point. Instruction-PS
25	Nothing much except the issues of practical, further explanation are required before writing the lab report. Content-R
26	The instructional approach was very helpful to us. Instruction-PS
27	No comment
28	No comment
29	Try to shorten the video since some are too big and at times, we encounter problems when downloading them due to their size. Video-R
30	After every test written we must at least be given back the scripts before commencing another test or activity so that we can be motivated by seeing our performance. Feedback-R
31	Assessment should not always be on multiple choice, leave learners to explore. Assessment-R
32	No comment
33	Please show how the concepts link to each other after and before completing the course outline. Content-R
34	We should have semester calendar where we are told when we will write quizzes, and test, because sometimes we write under pressure. Guidance-R
35	No comment
36	No comment
37	No comment
38	Satisfied with everything so far. Instruction-PS
39	No comment
40	No comment
41	I, everything was clear because in video when you want to reverse so as to get more clarity you do that. I strongly recommend studying using a video. Video-R
42	No comment
43	The instructor should give scripts back for students to know where they lack before writing many tests. Feedback-R
44	No comment
45	No comment
46	Giving more problems in class to discuss and work on them it will help a lot and try to increase the number of practical to perform the experiment so that students see that the theory part is real. Post class activity-R/ Content-R
47	No comment
48	Increase the level of difficulty of your assessment. Assessment-R
49	No comment
50	I am fine with how you taught this module. You created a room for us to go an extra mile to find information and still give us additional reading material which help a lot. Instruction-PS/other learning material-PS
51	No comment
52	The lecturer, you are one of the best lecturers in school of education, I benefit a lot from your lectures / class. You inspire to be a good science teacher. I

	never missed your class because of how you conduct it, it's not waste of my time attending your class. What I can say is to complement you even though there is always a space for improvement, but I don't see one. Lecturer-PS
53	No comment
54	Do not give us a lot of work two weeks before our semester work course end as it has a lot of impact on our academic performance. Post class activity R
55	More videos must be provided with more examples. Video-R
56	The tests sometimes are challenging. The teaching approach he is using help us to think critically and understand the topic. Assessment-NS / instruction-PS
57	To improve the way this module was taught, there should be slides or at least a prescribed book for which students should read and study other concepts using the slides and the prescribed book not only the videos. Other learning materials R
58	I suggest that we can be given problems that are a bit understandable and that we can solve them during tests. Assessment-R
59	No comment
60	No comment
61	Good. Instruction-PS
62	After writing a quiz, let the student and lecturer discuss the concept as if the video was never watched so that it emphasise and completes what is not stated in the video. Video-R
63	No comment
64	The level of difficulty for your tests are tricky but educative since you provide feedback. You encourage and trigger scientific thinking. Assessment-PS
65	No comment
66	The lecturer, you have done a lot. You only take a horse to the river, but you don't force it to drink. Lecturer-PS
67	No comment
68	Keep on using the method of videos. It accommodates many plus me. After watching a video, a short summary must follow in class to cement the information from the video. Video-R
69	No comment
70	No comment
71	The way the lecturer gave use the activity to discuss in groups it benefit us because we share though while discussing in the classroom. Everything so far so good. Class discussions-PS
72	I think even the study guide materials should also be provided in black board, not only videos because some of the learners learn better by preferring the study guides materials. Other learning materials R
73	I wish the instructor can download more of ray tracing diagrams of different lenses and mirrors so that we have clear pictures of what is happening without doubting. Content-R
74	The instructor delivers the content of the module very well and very understanding. Lecturer-PS

75	No comment
76	No comment
77	We were not given feedback on the tests we did every day in class which needs to improve. Feedback-NS
78	No comment
79	No comment
80	Too much of demanding questions are asked in tests compared to class discussions and this should at least be balance but lessons are always fair. Assessment-NS
81	No comment
82	No comment
83	No comment
84	No comment
85	No comment
86	No comment
87	A lecturer can aid video presentation with clarities during lectures. Class discussions-R
88	No comment
89	No comment
90	No comment
91	No comment
92	No comment
93	No comment
94	No comment
95	No comment
96	No comment
97	No comment
98	Assist in lab practical. We are getting wrong readings and error that are over 100% which can lower our practical marks. Guidance-R
99	The need of guidelines on pre- laboratory design and why, how we do it. guidance-R
100	No comment
101	No comment
102	No comment
103	The videos should be accompanied by questions. Video-R
104	No comment
105	No comment
106	Make us to discuss exam questions of all what we did exam type. Post class activity R
107	No comment
108	My appeal is that don’t just give us lot of work because you feel like because is too much to us at some point. Post class activity-NS
109	No comment
110	Give students much time to prepare quiz and tests. Assessment-R
111	No comment

112	No comment
113	No comment
114	No comment
115	They should give us more time to attend the class and the period should be also at weekends. Post class activity R
116	Tests and quiz written are demanding and difficult to answer due to time given and less feedback given in class presentation and discussion. Assessment-NS / Feedback-NS
117	No comment
118	The way the module was taught was perfect. No improvement needed as far as I am concerned. Instruction-PS
119	The lecturer should at least provide feedback on written tests whether the students have done well or not and engage them in order to improve their performance. Feedback-R
120	No comment
121	The videos should not take too much time like 45 minutes because we end up forgetting what you saw in the first minute. They should be short and based on a certain topic in a concept. Video-R
122	No comment
123	Everything was good and smooth. I hope and believe that I will get a distinction. That was the best lecture I have ever had. Instruction-PS

Student ID	Coded comments
1	No comment
2	No comment
3	No comment
4	No comment
5	No comment
6	The lecturer was explaining everything in class, he was even asking where we don’t understand just to clarify us. Lecturer-PS
7	Sir when setting the exam paper, bring 50/50 question more challenging and less challenging, not just challenging questions only. Assessment-R
8	I have never done this topic before. Content-NS
9	No comment
10	Very good work let’s hope we will meet your paper in exam room we are already prepared since day one. instruction-PS
11	No comment
12	Promote individual work than group work. Class discussions R
13	No comments
14	No comment
15	Carefully listen to the learners’ queries and try to clarify them the way they can be satisfied. You do good but remember that a room for improvement must always be there. Thanks. Class discussions-R
16	Videos help much because other learners can feel that they are included because we learn in different ways. Video-PS

17	I wish to go with the instructor to final year, because he is not interested in marks and memorising, his interest is understanding the concept that is being taught. Lecturer-PS
18	The method of learning should be used more often as it helps students to learn better and it covers the scope within a short space of time, revision is always ready as one can replay the video. Instruction-PS
19	The video watching strategy was good and understandable. The instructor must put more videos. Video-R
20	No comment
21	More practical work on different problems or bringing apparatus to class for demonstration. Post class discussion-R/Class discussions-R
22	No comment
23	No comment
24	Like I said everything was exquisite, all was left of me is to work as a student. Instruction-PS
25	No comment just wish the presenter could continue doing a great job and thanks for that. Lecturer-PS
26	I think this module was taught far better than the other previous modules because I have understood the concepts far much better than before. Instruction-PS
27	No comment
28	No comment
29	No comment
30	Comparing from last year's physics, I think the use of videos has been a great deal, it improved a lot on our performance. I admire the idea and I as a teacher I am going to try and implement it as I go for my teaching practice. Video-PS
31	No comment
32	No comment
33	I support the method used to instruct the module. Instruction-PS
34	Special appreciation to the lecturer, I am inspired by your commitment on us. It is very clear that you want us to be better teachers in the in the future. God bless you. Lecturer-PS
35	No comment
36	No comment
37	No comment
38	The method used could also lead to great academic performance if used again in the next semester. Instruction-PS
39	No comment
40	No comment
41	You are strongly recommended. You are a good lecturer. Lecturer-PS
42	No comment
43	No comment
44	No comment
45	The videos really played an important role in our learning. They are clear and well understood and interesting. Video-PS

46	Give more videos and let the students have a presentation about the topics and record them by video or audio to show the next group what others have done. I think it will inspire them. Video-R
47	The way this module was taught was very good than the way I was taught Physics in previous years. The lecturer was moving at the same pace with us and providing feedback after writing any quiz or activity. He does the corrections with us all the time and this helped me a lot because I was able to see and rectify my mistakes. Instruction-PS
48	You should give us more practice questions related to the exam on blackboard when we are at teaching practice and when we come back to others it is easy to forget. You should use continuous assessment to monitor our progress and that we do the same. Post class activity-R / Assessment-R
49	The level of questioning in the tests is not the same as when we are in class. Assessment-NS
50	I suggest sticking to working in pairs for every activity and if it is practical its fine with 5 people. When you give us class activities its better, we submit the next day. Send us videos that were created by you because it will ascertain us that what you compiled there will assure us is the right thing or right information you would like us to be aware of and you can also emphasize on points you see them important. Class discussions-R / Video-R
51	No comment
52	Sir as I have said you possess all the traits of my ideal teacher. I wish one I could be able to conduct or present my lessons just like yours. Lecturer-PS
53	Videos help us to gain a lot because we can even watch them after the lesson unlike being taught. Video-PS
54	It has helped to raise curiosity in learning Physics and helped me to have confidence in myself that I can do well in Physics. Instruction-PS
55	No comment
56	I am interested in this module since the participation in class discussion takes place during lecture and I am able to understand from where I am lost. Class discussions-PS
57	The module was presented good using ideas because after each video we wrote a quiz to check on our understanding of the concept that was taught in the video. Assessment-PS
58	No comment
59	No comment
60	No comment
61	Excellent. Instruction-PS
62	This method of video watching should be used more often as it caters even those that cannot learn best during discussions. Video-R
63	No comment
64	It seems like all reading without extra technological material does not accommodate all learning styles and it does not intrigue like media does. Video-PS
65	No comment
66	Change of strategy is better for understanding like we did. Instruction-PS

67	I am satisfied about how this module was conducted. The videos gave me better understanding of this module. Video-PS
68	Video styles was a game changer and writing lot of assessment develop the greater passion for the module. Video-PS / Assessment-PS
69	No comment
70	More videos. Video-PS
71	The way the module was taught is very good because each and every student is forced to watch the video and bring the knowledge that he /she saw in the video into the class for discussion. Video-PS
72	No comment
73	No comment
74	No comment
75	No comment
76	No comment
77	No comment
78	In the way this module has been taught it was a great teaching method. It helped me a lot. Instruction-PS
79	No comment
80	The lecturer should be pitiful in examination as he always was at all other activities during the year activities. I feel like I can continue with physics being taught by him. Lecturer-PS
81	No comment
82	No comment
83	No comment
84	No comment
85	I like the fact that our lecturer wanted us to learn rather than competing, but feedback is very much vital having our scripts back and reflecting on them. Lecturer-PS/Feedback-NS
86	No comment
87	The method used for hpha031A Physics is far much better than that used for 021/022. Instruction-PS
88	Always give feedback to address some of the unclearness we have when discussing. Feedback-R
89	No comment
90	No comment
91	No comment
92	No comment
93	No comment
94	I think part of the Practical has to be included in the exam eg: the state the hypothesis of the experiment, set up diagram, or investigative question. Assessment-R
95	No comment
96	We have to have the script for the test and quizzes to see our areas of difficulties so that we can improve on them. Feedback-R
97	There is nothing to add you are at the best level. Lecturer-PS

98	It is much better than before. Instruction-PS
99	No comment
100	No comment
101	No comment
102	No comment
103	No comment
104	No more comment but please continue with this method of videos on blackboard. It is a very clever strategy. Videos-R
105	No comment
106	The module was well presented. Instruction-PS
107	No comment
108	Don’t bring too many tasks to do as activities to submit because we do them, but we don’t get the feedback afterwards and I am requesting you to make sure that after writing a test and you mark it please provide a feedback. Feedback-R
109	No comment
110	Bring feedback on time. Feedback-R
111	No comment
112	No comment
113	No comment
114	No comment
115	They must provide us at least with one book only. Other learning material R
116	The way the module has been taught compared to the way it was previously taught is good. Even though things are tough, but the facilitator tries his best to meet us halfway. Instruction-PS
117	No comment
118	No comment
119	No comment
120	No comment
121	No comment
122	No comment
123	The module was taught in an excellent way and understandable way. Keep it up. Instruction-PS

APPENDIX H

Sample of analysis of the open-ended questions' responses

<table>
<tr><th>Strengths</th><th>Weaknesses / Challenges</th></tr>
<tr><td>Content
• The content was well presented clear to everyone
• Everything was clearly outlined
• The content is understandable</td><td>• Fermat's principle is what we have not discussed
• More practical work
• Work on videos which talks about index of refraction and proof of the laws & calculations not well articulated
• Ray model is treated from refraction on videos but while in books they use water waves and light and this makes it difficult to understand
• Sign convention not covered properly
• Sign convention were a bit cumbersome
• Content difficult to understand due to lack of adequate matric background
• Some examples of deduction of formulae were given in class but some he didn't further explain
• Clear explanations must be given to learners after they have watched the video
• Lab practical, further explanation are required before writing the lab report
• Increase number of experiments to be performed so that students see that the theory part is real
• The instructor should download more of ray tracing diagrams of different lenses and mirrors
• They should give us more time to attend the class and the period should be also at weekends
• More lab practical work on different problems needed
• Bringing apparatus to class for demonstration
• Part of lab practical has to be included in the exam</td></tr>
<tr><td>Assessment
• Work provided relevant to what was assessed in quiz and tests - don't know about the exam
• The quiz before the lesson starts really helped me
• Quiz helped to students to prepare before going to the class
• Writing a lot of assessment develop the greater passion for the module</td><td>• Assessment should not always take place
• Level of difficulty of questions was very high and so challenging
• Give two test, one simple and one difficult, but not always a difficult test
• Assessment should not always take place
• Assessment should not always be on multiple choice
• Increase the level of difficulty of your assessment
• The tests sometimes are challenging.
• Given problems should be understandable and</td></tr>
</table>

	that we can solve them during tests • The level of difficulty for tests are tricky though educative since feedback is provided. • Test questions demand more compared to class discussions • Give students much time to prepare quiz and tests • Tests and quiz written are demanding and difficult to answer • Bring 50/50 questions more challenging and less challenging, not just challenging questions only tests • Use continuous assessment to monitor our progress • Level of questioning in the tests is not the same as when we are in class • The lecturer should be pitiful in examination • Do not give us a lot of work two weeks before our semester work course end
Feedback • The lecturer was moving at the same pace with us and providing feedback after writing any quiz or activity	• Integration of feedbacks needed • Provide student scripts in order for them to see where they went wrong • Clear and proper feedback from the instructor is requested • Give back scripts before commencing another test or activity • Instructor should give scripts back to see where they lack before writing the next test • We were not given feedback on the tests • Less feedback given in class presentation and discussion • The lecturer should at least provide feedback on written tests • Feedback is very much vital having our scripts back and reflecting on them • Always give feedback to address some of the unclearness we have when discussing • We have to have the script for the test and quizzes to see our areas of difficulties so that we can improve on them • After writing a test and you mark it please provide a feedback • Bring feedback on time
Videos • Video watching is time serving • Videos must be used in future lessons • Prefers videos than the lectures • Videos preferred most than classroom lessons • Videos can be repeatedly played • Material on video can easily be recalled than material in reading books	• More videos must be provided with more examples. • After writing a quiz, let the student and lecturer discuss the concept so that he emphasise and completes what is not stated in the video • The videos should be accompanied by questions • The videos should be short and focused on a specific concept in a topic • Give more videos and let the students have a

• The videos were helpful • Videos given to us are helpful • Videos have the advantage they can be repeated several times • Teaching strategy was best when your own recorded videos are used • Videos accommodate 95% of the students in the classroom • Videos more helpful because they could be replayed • The videos are very helpful because they could be watched when we were away on teaching practice. • Videos are really helpful especially when explanation are not clear or given in class, on videos we can watch again and again & gain more understanding • Knew most of the things because of the videos • Videos must be used on each lesson because it's understandable and recallable. • Strongly recommend studying using a video • Keep on using the method of videos • Videos accommodate different learning styles • The video watching strategy was good and understandable. • The instructor must put more videos • Use of videos improved a lot on our performance • Videos really played an important role in our learning- are clear and well understood and interesting • Videos help us to gain a lot because can even watch them after the lesson • After each video we wrote a quiz to check on our understanding of the concept that was taught in the video • Videos should be used more often as they cater for those that cannot learn best during discussions • Reading without extra technological material does not accommodate all learning styles and it does not intrigue like media does • Videos gave me better understanding of this module • Video styles was a game changer • Each and every student is forced to watch the video and bring the knowledge that he /she saw in the video into the class for discussion • Some videos show deduction of formulae and explanation and sign convention though others not	presentation about the topics and record them by video or audio • Lecturer must create his own to assure the right information you would like us to have is there • More videos will be helpful, students understand well better than reading theory • More videos will be helpful

Class Discussion • Difficult problems were discussed in class • Group discussions benefited students; ideas were shared during discussions in class • Participating in discussions help where one is lost	• Should include presentation with comments from lecturer, and students giving brief valid scholarly reasons • Giving more problems in class to discuss and work on them will help a lot • Summarise video material in class • Aid video presentation with clarities during lectures • Make us discuss exam questions of all what we did • Let students work in pairs for every activity and if it is practical its fine with 5 people
Guidance	• Show how the concepts link to each other after and before completing the course outline • Provide semester calendar showing when we will write quizzes, and test to minimise pressure • Carefully listen to the learners' queries and try to clarify them the way they can be satisfied • Assist in lab practical where students get wrong readings and errors • The need of guidelines on pre- laboratory design, why, and how we do it.
Instruction • Satisfied with how the content is delivered in comparison to other years • The module was well presented-can be revisited if not properly understood • Method should be used in other semesters because its enjoyable and one gains knowledge • The lectures were excellent • Generally, method benefited students even with better grades • Method accommodates different learning styles of students • Method should continually be used in coming semesters • F to F contact sessions interesting • A very powerful method of teaching • Enjoyed the lectures, module was taught well • Everything was on point • Instructional approach was very helpful • Satisfied with everything so far • Benefited a lot from lectures • Teaching approach he is using help us to think critically and understand the topic • Instruction was good • The way the module was taught was perfect • That was the best lecture I have ever had • Instruction was good. • Method of learning helps students to learn better • Method of learning covers the scope within a	

short space of time, revision is always ready as one can replay the video • Instruction was good • Support the method used to instruct the module • Method used could also lead to great academic performance if used again in the next semester • The way this module was taught was very good than the way I was taught Physics in previous years • It has helped to raise curiosity in learning Physics and helped me to have confidence in myself that I can do well in Physics • Change of strategy was better for understanding • It was a great teaching method • I feel like I can continue with physics being taught by him • Method used for this module far much better than that used for other modules • It is much better than before • Please continue with this method of videos on blackboard, it is a very clever strategy • The module was well presented • The way the module has been taught compared to the way it was previously taught is good • The module was taught in an excellent way and understandable way	
Learning Materials other than videos • Gave us additional reading material which helped a lot during in and out of class activities.	• More materials should be provided with examples of how to solve problems using the appropriate principle • Do not give us a lot of work two weeks before our semester work course end • There should be slides or at least a prescribed book for which students should read and study other concepts other than videos • Even the study guide materials should also be uploaded on black board • They must provide us at least with one book only
Lecturer • The lecturer best presented his lessons. • The lecturer really passionate about his work. • Keep up the good work. • The lecturer, you are one of the best lecturers in school of education • Lecturer encourages and trigger scientific thinking • The lecturer, you have done a lot • The instructor delivers the content of the module very • The instructor delivers the content of the module very well • The lecturer was explaining everything in class, asking where we don’t understand	

• Instructor's interest is understanding the concept that is being taught • Lecturer should continue using this new method • Module taught better than the other previous modules • Special appreciation to the lecturer • Lecturer strongly recommended • Wish I could be able to conduct or present my lessons just like yours • The lecturer wanted us to learn rather than competing • There is nothing to add you are at the best level • Even though things are tough, but the facilitator tries his best to meet us halfway	
Post class activity • A lot of work to do given that enabled us to practice • You created a room for us to go an extra mile to find information	• Lot of work given for practice make us loose concentration • Reduce workload for students to reduce pressure • A lot of work was given in a limited space of time • Give us more activities to work on, the type of questions that can sharpen our understanding • Don't just give us lot of work because there is no time to cover it all • Promote individual work than group work • Give us more practice questions related to the exam on blackboard when we are at teaching practice

Note: Table below compiled by counting number of bullets on each theme in the table above.

Code	Theme	Count	Count as (%)
1	Content	19	11
2	Assessment	21	12
3	Videos	39	22
4	Feedback	14	8
5	Class discussions	9	5
8	Guidance	5	3
9	Instruction	35	20
10	Learning material other than videos	5	3
11	Lecturer	19	11
12	Post class activity	9	5
TOTAL		175	100

APPENDIX I

Student Interview Protocol

INTRODUCTION	STUDENT CONSENT FORM
Key Issues: • Thank you • My name • Purpose • Confidentiality • Duration • How interview will be conducted • Opportunity for questions • Signature of consent	I want to thank you for taking the time to meet and speak with me today. I would like to talk to you about your experiences participating in the new method of lesson delivery namely: **video watching, video assessment, and in-class activities** used to teach GO during first semester. The interview is part of an evaluation of this instructional approach, and I am assessing the effectiveness of this instructional approach in order to capture lessons that can be used in future interventions. The interview should take an hour or less. The interview will be digitally recorded and transcribed because I don't want to miss any of your comments. Because we are on tape, please may you speak up so that I don't miss your comments? This interview will be kept confidential. This means that your responses will be only used for the purpose explained to you and information included in the final report will not identify you as the respondent. Please take your time in answering. You don't have to talk about anything you don't want to. You do not have to take part in this interview if you do not wish to do so and can withdraw any time you wish without any consequences. However, your views are important, bearing in mind that future students will benefit from your contributions which shall be used to improve this instructional method. Do you have any questions for me before we start? Are you willing to participate in this interview? If "YES", please sign in the space provided below as confirmation of acceptance to undertake this interview. ____________________ _______________ Interviewee Date

<table>
<tr>
<td>

QUESTIONS

Key Issues:

- Introductory statement

- No more than 15 open-ended questions

- Ask factual before opinion

- Use probes as needed

</td>
<td>

Now that we have completed the consent form, I will now ask you to express your own views and experiences about the instructional approach used to deliver the GO course content during first semester. A tape recorder will be taping what you say for my records and these will be kept securely, and your name will not be used anywhere. Your answers will be looked at together with those of other participants who did the same module with you and you will not be identifiable in any reports that are published.

It is very important for me to hear your views and experiences because you have gone through the module. I hope you will have time to spend with me now to complete this. I am going to turn on the voice recorder now. Don't forget you can ask me to turn this off at any time.

Would you mind briefly introducing yourself?
Name, level, and major

1. How would you describe the content you learned in this course? Would you please explain?
2. Did this instructional approach/method in any way improved your ability to solve challenging problems in physics? Would you please explain?
3. Was there some kind of assistance/extra help you could get after class regarding some things you may not have understood during lesson time? Would you please explain?
4. How would you describe the classroom interactions?? Would you please explain?
5. How would you describe the way the course was delivered in general? Would you please explain?
6. How would you describe the teaching and learning materials used in the module? Would you please explain?
7. How prepared were you for the exam after going through the module? Would you please explain?
8. What were the limitations/weaknesses of this instructional approach? Would you please explain why?
9. How would you describe the way the main concepts of the GO topic were sequenced/organized for teaching: 1. Ray model, 2.

</td>
</tr>
</table>

	Refraction, 3. Reflection? Would you please explain? 10. How would you describe your laboratory sessions?
CLOSING **Key Issues**: • Additional comments • Next steps • Conclusion • Thank you	Is there anything you think is important about how this module can be taught, that we have not talked about, you would like to add? I'll be analysing the information you and others gave me as part of my studies. That's all the questions I had for you. Thank you for your patience and co-operation. I truly appreciate this. I will be in touch should anything come up for which I might need your expert view on and will be available should you need to contact me for any reason related to this interview. Thanks again for everything, have a good day / evening.

APPENDIX J

Sample Response of Interviewee

Participant # 06: Interview session 2017 ($P6_{2017}$)

R: We can start. My first question is, if you can just briefly tell me your name, your study level, what you are majoring in and in which year you are.

S: OK my name is X. I am majoring in mathematics and physical sciences, and I am in Level three

R: That's for now in 2017? OK my first question is, how would you describe the content you learned in this course of geometrical optics

S: OK, the content, I thought at the beginning, I thought the content was very difficult. It was very easy but as time goes by, I realized that I can't relate some of the things I learned in the content in real life situation. For example, when we're looking at the reflections of light, looking at the different colors, I could tell that, I could relate that, OK we are looking at the frequencies and what and what not, but then as time goes by, I can't relate why sometimes when the light, when we say the light reflects, we can't see, we can't see some of the things from the distance that's why I can say this this content was very difficult in a way and then also it was challenging. I could read and think that I understand but then when test comes, I could see I'm not ready for the test

R: OK, let's see question number 2. Did this instructional approach or method in any way improved your ability to solve challenging problems in physics? By the way I mean the approach you were using was to watch videos before you come to class and then when you are in a class then you discuss problems that were on worksheets given by the lecturer. Now, did you find this method improving your ability to solve difficult problems?

S: No, I didn't find it helpful in solving difficult questions, because the videos were selective. Like, the videos were not generally including everything that we were learning in the module. Maybe the lecturer was looking at some things and those things some of them are not all in there in the video or some are not part of our objectives we may be doing some things, we may be seeing some things in the lecture, in the videos that that are mentioned as our objectives but at the end of the day we realise that some of the things are lacking in the videos some of the things the videos are not stating everything that we should learn. They are just stating the basics, that's why I didn't find them helping me to solve the challenging problems in physics, but then somehow the videos helped me to helped me to check to search for more videos on YouTube so that I can learn some of the things that are not in the video.

R: OK so you are saying though the videos were not having all data but, in a way, they motivated you to search for more videos on online

S: Yes

R: OK, now we look at question #3. Was there some kind of help which you got after class when the lesson was over? When you were still engaging in the material you discussed in class and sometimes you may have found areas that are difficult for you to understand, were you able to get some form of help? If so, who helped you or who was helping you?

S: The only help that I received in the in this module was when I was approaching to write the test or the exam, because I am doing a lot of modules, and I have a lot of work to do academically. So but yeah, I got help from my friends, where I couldn't understand some of the concepts in this module, and then I got some assistance, I checked for other questions, related questions on google, some videos on YouTube and also I got some questions in the prescribed book the Carnell and Johnson.

R: OK when you say from your friends do you mean your group members or members outside your group members allocated to you in class?

S: From my friends, not my friends from the group, but then from the class.

R: OK let's see question 4. How would you describe the classroom interactions that were happening in class when you were given work to solve in groups, and then afterwards you had discussions in general together with the lecturer? How do you feel about those interactions?

S: About the interactions, when we were discussing, the lecturer gave us different questions in our respective groups. So, in class I would only focus when we were discussing our question, and when we’re discussing other questions, I didn't see them as important. Then at the end I didn't understand what we were discussing about. I didn't really study. I didn't really pay attention to the questions that the lecturer didn't give me or to our group. I only concentrated on the discussion concerning our question.

R: What was the reason for you not to pay more attention to the other questions which were not allocated to your group?

S: Because I thought maybe we are just doing these questions for the sake of doing them. We were kind like, learning, I thought, when discussing, when I understand what I was doing with my group, maybe I will understand everything that they're doing. I thought everything, every question that the lecturer gave us was the same as other groups, may he just have changed here and there, the lecturer, just changed here and there.

R: Oh, do you, would you have preferred another way of having problems, in other words would you have preferred the lecturer to give everybody the same problem, do you think that could have helped you.

S: Yes, I think if the lecturer gave us all the questions. If the questions were twenty and gave us all and asked us to work on them, unlike saying question one goes to Group One, question two goes to group whatever. If he said this are twenty questions and you have to work on them all, all of them as a group. Maybe that would have helped me would have helped me to concentrate.

R: OK let’s look at question 5, but before we go to question five, let me ask you again something on question four. Your group members were they contributing much to solving the specific problem given to you.

S: Actually, with my group members, we were just focusing on that question that the lecturer gave us and then that was it, but then yeah, they did contribute, and I learnt much from them.

R: Did you have any moment where you would say one of your members was not forthcoming or helping in solving your problem

S: Yeah, some we would discuss as a group, we would say, ok here is the question, we are going to do it and then would come together and discuss it. Bu then you would find that we were five in the group, you find only four wrote something about the question and then the other one didn't write anything, and when we ask him, he would say, I didn't understand. So, you would have to explain everything to him, explaining and that way we were learning.

R: How did you form these groups? Were they allocated to you by the lecturer, or you formed them yourselves?

S: We formed them ourselves because we are friends of fifteen. We are friends in our group. We are fifteen and then we just said, ok these five would go to this group, and these five will go to this one.

R: Ok if you were to re-form the groups, would you still prefer to work with the same members?

S: Yeah, I will still prefer to work with them because they do encourage us to. Even during the exams, we do study together, and then when we write, we write like questions, we write what we discuss in class, and then during exam time, or tests, we discuss what we understood from class as a group.

R: Ok let's look at question 5. How would describe the way the course was delivered in general. By this, I am saying, did the approach used, the method used, make you think or forced you to discover things on your own, like go on to read further by yourself? How do you feel about it?

S: Ah this module, this one of geometrical optics, it just brought wonders to my mind, how are these things happening. And then from there, I would want to discover what is really happening, but then from my studies I couldn't. I couldn't do it because I have a lot of work. Other modules are demanding my time. So, I couldn't. I just used what the lecturer gave us, to study for the exam.

R: Ah, when you say you had no time, you had many modules, how many modules were you doing?

S: I was doing six modules.

R: six modules.

S: Uhm.

R: And these modules demanded most of your time.

S: Yes.

R: Ok, let's see question 6. How would you describe the teaching and learning materials listed in the module? Here we are looking at the videos, the quality of the videos, the content in the videos, the textbook you were using, accessibility to online materials. How do you feel about those materials?

S: About the videos, let me start by talking about the prescribed book. The book had a lot of information. I read the book and watched the videos, because I would do that whenever I want to study for the test. I would check the videos and then together with the textbook, but the videos were not saying much like the prescribed book was saying. So, that would give me some challenges. I wouldn't know what I should study because this video was saying this, but then this textbook was telling me something else. But then, the online worksheets were very helpful when I relate them to the videos and the book, because some of the questions that came in the test or the exam, I would have found them before on the Internet.

R: If, suppose you were to give advice to the lecturer on designing the videos what would you advise him to include or not to include in the videos?

S: When the lecturer record the video, he should look at the book and say Ok, this is what the students are expected to do in my video. I should include each and everything, not just touch there and then, not just the basics, but then what is really needed. Ok, like I was saying, when the lecturer recorded, he should look at what are these learners, what are these students expected to learn. I should make sure that my video covers, include everything that they should learn, not just the basics.

R: But would that not make the video too long?

S: That would make the video too long, but then it will be, it won't be, it won't be too long for us if we can relate everything that is in the video to be from this book, we can relate this book and the video and then, I think it would be interesting. To say Ok, this is what this video is saying, and then yeah, here in the book they are elaborating it, they are emphasizing everything about what this video is saying.

R: OK, so what about, let's say, the way the content was being explained in the video, was it understandable?

S: It was very understandable, and it made us think that this geometrical optics course is very easy, but then you know it was deceiving us, because it was only stating the basics and obviously the basics are always easy.

R: So, if let's say you wanted something which is not basics in the video, what kind of things would you expect to be there?

S: Like things, when I say the basics, I mean maybe you say ok these are the objectives, and then you just explain these objectives, and then when I mean the videos should not state only the basics, I mean that the video should also show us how to explain something diagrammatically, how to draw those rays how, how do they relate to each other, how does this ray model, the refraction, the reflection, relate? Like all those concepts, like in the ray model, how is this used in the reflection, how is this used in refraction, it should state how the ray model relates to reflection and refraction.

R: The videos you were given by your , were they made by the lecturer, or were they downloaded from online?

S: They were made by the lecturer.

R: They were videos made by the lecturer, ok, and alright, now let's look at question 7. <u>How prepared were you for the exam after going through the module?</u> That is, how the module was taught, the method that was used, the videos and class discussions, so how did these help you to prepare for the exam?

S: I can't say the videos had an impact on my preparation for exam because, for exam I was not prepared but then it was not because of the videos. It was only because I didn't have enough time to study, to relate my videos to, I just used the videos and the worksheets from the internet, and my problem was that I didn't use my book, that is why I was not prepared when I was going to write the exam

R: OK, let's look at question 8, what were the weaknesses of this instructional approach? What I mean is, as a method of teaching, you would go and watch videos, then come back and discuss in class. What weaknesses do you feel were in that kind of approach of teaching?

S: We would go and watch the videos and come back to class, and then, if I have watched the video, in the class I would see the class discussion very productive. But then if I didn't watch the videos then that was something else. So, the weakness with the video is that, I can say, I can think that I have learnt everything from the video, I could watch the video and go back to class and when I get there I can see, here is, I have seen this in the video but then now that these, my classmates, are saying something else. And then, I understand this and then this would be, will give me distractions, I will even get confused at sometimes when I take the information from the videos and relate it to the class discussions, and then with the quizzes sometimes I can watch the video and then find out that the video didn't have enough information, and then there I would find the quiz very difficult even the test.

R: Ok, now let's look at question 9. The material in the course was divided into three units. The first unity was the ray model, the second unit was refraction, the third unit was reflection of light. What is your opinion about the arrangement of these topics? Would you have preferred the arrangement to be in another way?

S: No, the way the arrangement was, I think was very fine, because I could relate from ray model, I could see the relationship when we go to the refraction, and then when we go also to the reflection. I don't see any problem with the arrangement of the topics.

R: OK let's look at the last part of the question 10. What I want to know is, is there anything which you think you might need to add, which we have not discussed, but you feel you want to say something about this method of teaching?

S: I think when you teach this module, you should consider doing the practical, we should have all the apparatus, do we call them apparatus, everything that is needed so that when we learn, when the lecturer tells us this, we should see it happening somewhere, because as I am an educator, and a student teacher, I find it difficult for me to do the practical of light, when I get to school, since I didn't do them here. I can't learn them there. I should be taught first before I teach other learners.

R: OK, thank you very much. I will be analyzing this information for the purpose of improving this approach in future. Anything which you might feel you want to add to what you have said at any time in future, you are free to come and tell me.
S: Ok.

R: thank you very much OK.

***Note*: R stands for researcher: S for Student**