A Persuasive Educational Technology-Based Tool for Motivating Junior Secondary School Female Students in Nigeria to Enrol in STEM

by

AISHA MUHAMMAD ABDULLAHI

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DECLARATION

Name: ___AISHAMUHAMMAD ABDULLAHI________________________________

Student number: __________67079229____

Degree: ______DOCTOR OF PHILOSOPHY IN INFORMATION SYSTEMS______________

A PERSUASIVE EDUCATIONAL TECHNOLOGY-BASED TOOL FOR MOTIVATING JUNIOR SECONDARY SCHOOL FEMALE STUDENTS IN NIGERIA TO ENROL IN STEM

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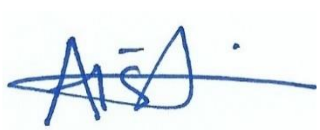
_________ ________ **May 15, 2024**________

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ABSTRACT

Background: Science, Technology, Engineering, and Mathematics (STEM) fields have made significant contributions to our modern world's advancements. However, the number of women in STEM professions in Nigeria is overwhelmingly low. Concerns have been raised about the growing demand for STEM skills and the shortage of human resources to meet this demand. There is advocacy to encourage female students to pursue STEM disciplines to meet the demand for STEM skills. Despite this, no research has been conducted in Nigeria to increase female students' enrolment in STEM using the attitude and behaviour change approach, also known as the persuasion approach. This is despite the strong support for research that focuses on the affective aspect of STEM learning, which deals with students' values, and believes to encourage female students' enrolment in STEM pathways.

Aim: The main aim of this thesis is to develop a framework that guides the design of persuasive educational technologies (PET) based on the persuasion approach to motivate junior secondary school female students in Nigeria to enrol in STEM classes.

Setting: The participants were drawn from three different secondary schools in Nigeria's Kano State. The research delved into the natural environment of the participants to ensure that contextually rich information was gathered from them to inform the study.

Method: Data was collected from the research participants through interviews and a focus group session and analysed using a qualitative research approach. Following data analysis, the Design Science Research (DSR) strategy was used to guide the framework design. The DSR strategy's rigorous iteration phases ensured that the framework was redefined several times until a rigorous artefact was produced.

Results: According to the study's findings, certain external factors (school factors, family factors, and cultural factors) influence female students' attitudes toward STEM professions, and it is their attitude towards STEM professions that guides their decision to pursue a STEM pathway. A motivational push from a PET can encourage female students to pursue STEM careers.

Conclusion: A PET tool developed following the PET4STEM framework has the potential to change female students' attitudes toward STEM professions and consequently their decision to pursue STEM careers in the future. The theoretical contribution of the study is the creation of a new PET4STEM framework that provides information on key components of a PET tool to promote STEM enrolment among Nigerian junior secondary school female students. Second, it establishes, empirically, the factors that influence female students' enrolment in STEM classes. Finally, it proposes convincing strategies for combating female students' negative perceptions of STEM subjects. Teachers, parents, and researchers who are unable to develop a PET tool can use these strategies.

Keywords: STEM Education, STEM Interest, Female Students, Attitude Change, Family Influence, School Influence, Cultural Influence, Individual Influence, Educational Technology, Persuasive Technology, Motivational Strategies, Pedagogical Approaches, Design Science Research.

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LIST OF ABBREVIATIONS

ACM	Association for Computing Machinery
ARCS	Attention, Relevance, Confidence and Satisfaction
BLT	Behavioural Learning Theory
COVID-19	Coronavirus Disease 2019
CSET	College of Science Engineering and Technology
DSR	Design Science Research
EVT	Evaluation Value Theory
IBL	Inquiry Based Learning
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IS	Information Systems
IT	Information Technology
GPI	Gender Parity Index
JSS	Junior Secondary School
LMS	Learning Management System
MUSIC	eMpowerment, Usefulness, Success, Interest and Care
NASA	National Aeronautics and Space Administration
NHS	National Health Service
NSF	National Science Foundation
PBL	Problem Based Learning
PET	Persuasive Educational Technology
PET4STEM	Persuasive Educational Technology for Science Technology Engineering and Mathematics
PjBL	Project Based Learning
PSD	Persuasive System Design
PT	Persuasive Technology
SCCT	Social Cognitive Career Theory
SMS	Short Messaging Service
STD	Sexually Transmitted Disease
STEM	Science Technology Engineering and Mathematics
TRA	Theory of Reasoned Action
UK	United Kingdom
UNISA	University of South Africa
USA	United States of America

GLOSSARY OF TERMS

Attitude: Refers to a certain way of thinking or feeling towards an object or an evaluative judgment formed by a person about something (Schlenker, 1978; Regan and DeWitt, 2015).

Attitude towards STEM: In extant literature, it is used to refer to the feelings, beliefs and values held about the enterprise of school STEM, and the impact of STEM on society, or scientists themselves" (Regan and DeWitt, 2015 p.1053).

Behaviour: Behaviour is an expression of feelings through words or feelings (Regan and DeWitt, 2015).

Persuasion: "An interactive process through which a given message alters an individual's perspective by changing the belief, attitude, or interests that underlie that perspective" (Miller, 1980 p.12).

Motivation: Motivation means to arouse, direct, and sustain an individual towards a goal-directed action.

Influence: This is to have an effect on the character, development, or behaviour of someone or something. These three terms (persuasion, motivation, and influence) would be difficult to differentiate in practice. This is because in all three there is a target behaviour, or goal, that the persuader/motivator/influencer wants her audience to achieve or succumb to. Hence, since this study is also concerned with encouraging the target audience to imbibe an attitude/behaviour, these three terms are viewed as the equivalent.

Persuasive Technology: A persuasive technology is a computer application, system, or device specifically designed to influence its users. In this thesis, persuasive technology is also used interchangeably with persuasive systems, persuasive application, or persuasive tool.

Pedagogies: This is the art, method, practice and approach of teaching academic concepts or theoretical thoughts.

Framework: A conceptual structure that is used to plan or decide something.

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

This study focused on developing a framework to guide the design of persuasive educational technologies to employ in motivating junior secondary school female students in Nigeria to enrol in science, technology, engineering and mathematics (STEM) fields. Thomas and Tee (2022) define a framework as a structure constituting concepts, constructs, and their relationships; Pelt et al. (2021) understand a framework as a well-structured interface that defines the protocols for component collaboration. This study recognises a framework as a structure constituting relevant and validated components of a persuasive system and their relationship for motivating junior secondary school female students to enrol in STEM disciplines. The study identifies the components constituting a Persuasive Educational Technology for STEM (PET4STEM) framework and discusses their relationships.

This chapter provides the background of the study to establish the context of the thesis. It presents the problem statement, leading to the research questions and accompanying research objectives. Chapter 1 also provides the scope of the study, a brief discussion of the research methodology and the study's contribution to the body of knowledge.

1.2 BACKGROUND TO THE STUDY

STEM fields have contributed substantially to the stability and advancements in the contemporary world (Floros et al., 2010; ButtePatil, 2012; Dragan et al., 2018; Sharma et al., 2022). In 2019, for example, when the COVID-19 pandemic engulfed the world, education, trade, and commerce would have been suspended, wrecking economies, were it not for technological advancements, enabling businesses, schools and healthcare systems to function (Gamage et al., 2022). Patients received remote medical care (telehealth), students continued their studies online, and employees could work from home. Subsequently, this increasing reliance on knowledge and application of STEM in various aspects of people's daily lives has led to an increasing demand for personnel with STEM skills (Xue & Larson, 2015; Deming & Noray, 2018; Reich-Shackelford, 2018; Black et al., 2021). The 2024 global gender gap report reveals that skills in fields like computer science, medicine and engineering are in very short supply, and the demand grew by more than nine million between 2012 and 2022 (World Economic Forum, 2024). The risk of the shortage of STEM skills can affect innovation by technologies and processes becoming obsolete, which can lead to stagnation in the economy, food production and healthcare systems (Abdullahi & Chimbo, 2023). Thus, it follows that the stability and growth of any country depend on the number and skills of individuals in STEM fields; hence, the need for individuals to occupy STEM professions to keep abreast of the increasing demands of the present day world (Akinsowon & Osisanwo, 2014; Xue & Larson, 2015; Deming & Noray, 2018; Reich-Shackelford, 2018; Fomunyam, 2019; Umar, 2019; Black et al., 2021; Sulai & Erasmus, 2022).

The number of women in STEM careers in many countries across the globe is overwhelmingly low (Ekine & Abay, 2017; Baird, 2018; Reich-Shackelford, 2018; García-Holgado et al., 2019; Hanson & Krywult-Albańska, 2020; Nevin, 2020; UNESCO, 2020; Card & Payne, 2021). Data from a report by the World Economic Forum revealed that in many countries around the world, males outnumber females as students, researchers, educators and employees in STEM fields (Turcotte, 2011; World Economic Forum, 2020). However, despite this global overview, some countries do indeed have a good representation of women in STEM fields, both at school and at the career level. In the Caribbean region, for example, female students account for 57% of students in STEM disciplines in universities and 45.4% of researchers in STEM careers (UNESCO, 2015; Mukhwana et al., 2020). However, there is concern about a different trend in developing African countries (Nnaka & Anaekwe, 2006; UNESCO, 2017; Egun & Tibi, 2010; The World Bank, 2020; National Bureau of Statistics, 2020).

In Nigeria, the country, which is the focus of the study, women with STEM skills only comprise 17 per cent of STEM researchers (National Bureau of Statistics, 2019a). Concerns exist around the growing demand for STEM personnel and professionals and the lack of human resources to meet this demand (Akinsowon & Osisanwo, 2014; Xue & Larson, 2015; Deming & Noray, 2018; Reich-Shackelford, 2018; Fomunyam, 2019; Umar, 2019; Sulai & Erasmus, 2022; Black et al., 2021). The need for more women in STEM goes beyond gender diversity quotas. According to Schiebinger (2015) with more women in STEM, there will be more gendered innovations. These are research that takes into account the sex and gender of their subject. Studies claim that such research assures excellence and quality in research outcomes. More women in SEM will also foster diverse and unique perspectives on research outcomes because both genders will bring their uniqueness into the understanding of the different aspects of research. Further, the socio-economic status (SES) of women can improve if they take up STEM professions and with SES having a correlation with several components of subjective well-being, including psychological health, emotional health, and satisfaction with life, this implies that women may be more likely to experience healthier well-being. In addition, more women in STEM have the potential to increase overall economic growth and development of a country. For instance, a study of 35 European countries between 1995 and 2019 revealed that gross domestic product (GDP) and GDP per person increased with an increase in STEM skills (Bacovic et al., 2022). Reading (2015) also predicted that the GDP of Australia would increase by $57.4 with only 1% of its workforce changing into STEM. These benefits are discussed in detail in Chapter 2 of this study.

Since women constitute almost half of the population in Nigeria (National Bureau of Statistics, 2019; National Bureau of Statistics, 2020), and their numbers continue to increase in schools (Ekine & Abay, 2017), it would be rational to expect an increase in the number of STEM skills in the labour market, but this is not the case. Research shows that many female students opt for non-STEM professions (UNESCO, 2024). Their choice of non-STEM professions over STEM professions has been attributed to numerous issues: Their perception of their inability to succeed in STEM disciplines (Awofala, 2017; Dada, 2017; Ekine & Abay, 2017; Fabiyi, 2017; Awofala & Lawani, 2020), their perception that STEM professions are more things- than people-oriented (Cross & Madson, 1997; Su et al., 2015; Eccles & Wang, 2016; Burns & Rice, 2018; Kuhn & Wolter, 2020) a prominent relational self, causing them to attach high values to societal norms; and stereotypes about STEM professions being for a select group of people with whom they do not identify (Jozefowicz et al., 1993; Anderman & Midgley, 1997; Chevalier, 2002; Fuligni & Zhang, 2004; Hijzen et al., 2006; Korpershoek et al., 2021).

No study has found any difference in brain composition that explains gender differences in engagement or enrolment in STEM subjects (Hyde, 2005; Spearman & Watt, 2013; Organisation for Economic Co-operation and Development, 2018), which suggests that the gender difference in professional choice is not cognitive, but rather affective (Abdullahi & Chimbo, 2023). There has been strong support for research focusing on the affective aspect of STEM learning—which deals with students' motivation, interest, values and beliefs—to encourage female students' enrolment in STEM pathways (Osborne et al., 2003; Regan & Childs, 2003; Tai et al., 2006; Ashby Plant et al., 2009; Maltese & Tai, 2010; Olsen & Lie, 2011; Ainley & Ainley, 2011; Hayden et al., 2011; Stelter et al., 2021).

In Nigeria, students choose their academic pathway in Junior Secondary School Three (JSSIII) (Enukora et al., 2003; Federal Ministry of Education, 2023). At this stage, they are allowed to choose one of three possible academic paths: science, arts, or commercial studies. This transition phase is significant because their choices here define their career paths. Subsequent transitions, such as from Senior Secondary School (SSS) to undergraduate or undergraduate to postgraduate levels, only allow students further specialisation within a broader discipline. Unfortunately, this is the stage in which students predominantly opt for non-STEM pathways (Abdullahi & Chimbo, 2023). Nevertheless, some tools are available to nurture their interest in STEM professions, including Persuasive Technologies (PTs).

Persuasive Technologies (PTs) are special types of ICT designed to promote desired behaviour changes by shaping and reinforcing attitudes or behaviours about an issue, action or object without using deception or coercion (Fogg, 2003; Filippou et al., 2015; Orji et al., 2018; Alslaity et al., 2024). PTs have been applied successfully to promote positive outcomes in many domains. For example, in the health domain, researchers have developed persuasive technologies to help people stop smoking (Graham et al., 2006; Khaled et al., 2009; Bascur et al., 2018 ; Alshahrani, 2024) in the energy sector, PTs have been designed to lower energy consumption (Taha et al., 2018 ; Nharreluga, 2023) and in the environmental sector, PTs have been designed to improve people's recycling habits (Bremer, 2020). The concept of PT is based on the conception that the behaviour or attitude of its users can be changed through technology using various persuasive strategies (Khaled et al., 2009; Alshahrani, 2024). Persuasive strategies are mainly influence cues converted into design features in the technology (Orji et al., 2021).

In the education domain, some research has been conducted on the use of persuasion as a pedagogical approach to teaching and creating interactive educational software that motivates students to acquire new knowledge and skills (Firpo et al., 2009; Mintz & Aagaard, 2012; Behringer et al., 2013; Marra et al., 2016; Ham et al., 2015; Orji et al., 2019; Engelbertink et al., 2020). For example, (Hsu et al., 2016) designed an educational technology for high school students to promote their desire to pursue surgical medicine.

1.3 PROBLEM STATEMENT

The need for individuals to pursue STEM professions to meet the increasing demands of the contemporary world is evident in research (Akinsowon & Osisanwo, 2014; Fomunyam, 2019; Umar, 2019; Black et al., 2021; Sulai & Erasmus, 2022; Katja & Froidevaux, 2024). In Nigeria, the situation is even more dire; only 17% of STEM researchers are women (National Bureau of Statistics, 2019a). The World Bank Global Report on Economic Gender Gap index ranked Nigeria 128th out of 153 countries globally and 27th out of 53 African countries (Nevin, 2020). With the increasing number of female students enrolling in schools (Ekine & Abay, 2017), there is advocacy to motivate female students to pursue STEM disciplines in school to increase STEM skills (Baird, 2018; García-Holgado et al., 2019; Hanson & Krywult-Albańska, 2020; Card & Payne, 2021).

As a result, various researchers have conducted studies focusing on increasing female students' enrolment in STEM by identifying factors affecting female students' enrolment in STEM disciplines (Eraikhuemen & Oteze, 2015; Maryann & Agommuoh, 2017; Rahman et al., 2018; Makarova et al., 2019; Plasman et al., 2020; Msafiri, 2024), by designing innovative STEM teaching and learning methods (Chittum et al., 2017; Stracke et al., 2017; Udu, 2018; Mäkelä et al., 2020; Richard & Brent, 2024) and by developing tools to sustain young women's engagement in STEM subjects (Audu & Ojekudo, 2016; Mellor, 2018; Sevari & Falahi, 2018; Kuen-Yi, 2023).

However, from the literature, there appears to be no research in Nigeria aimed at increasing female students' enrollment in STEM by focusing on the attitude and behaviour change approach, also known as the persuasion approach (Abdullahi et al., 2018; Abdullahi & Chimbo, 2023). The persuasion approach can be defined as "an interactive process through which a given message alters an individual's perspective by changing the knowledge, beliefs, or interests that underlie that perspective" (Miller, 1980, p.14). Persuasion has been applied in the learning domain to bring about positive attitudes and behaviours toward learning (Nayir, 2017; Linnenbrink-Garcia et al., 2018; Steinmayr et al., 2019; Tereshchenko et al., 2023). Blazar and Matthew (2017) explain that tutors and educators often have to deal with the need to reinforce or strengthen certain beliefs or behaviours in students to promote positive learning experiences. Hence, using persuasion as a pedagogical approach to teaching surpasses just helping learners assimilate new knowledge and skills; it rather involves changing learners' ideas. Advancements in technological design allowed persuasive cues to become integrated into technologies and thus used to influence students toward the desired learning behaviour.

Some studies have used PT as a tool to motivate positive learning behaviour (Lucero et al., 2006; Bamidis et al., 2011; Goh et al., 2012; Star et al., 2017; Engelbertink et al., 2020 ;Krishnamoorthy & Merchant, 2023)**.** For example, Orji et al. (2021) used a PT to motivate undergraduate university students to increase their engagement with online learning activities. However, the authors designed their PTs following existing frameworks such as the eight-step persuasive technology design framework, the functional triad framework, and the persuasive system design (PSD) framework (Abdullahi & Chimbo, 2023), all of which have limitations, including the following:

- According to Oinas-Kukkonen and Harjumaa (2009) and Wiafe (2016), the eight-step design framework provides suggestions for the early stage of PT design but not an in-depth suggestion for PT design. The reason is that the framework failed to provide suggestions for persuasive design principles for the designer to employ. Consequently, designers who follow this framework are left to rely on other successful PTs for options in the implementation of persuasive design principles, as was the case with Orji et al. (2021), who had to identify successful PTs to imitate.
- The functional triad framework indeed provides suggestions for persuasive design principles yet fails to describe how persuasive design principles can be converted into actual system features so that designers can easily operationalise such persuasive strategies in PTs. Designers employing this framework still have to do the bulk of the work in converting persuasive design principles into system features.
- The PSD framework describes how persuasive design principles can be converted into actual system features but does not focus on any specific domain. According to Wiafe (2016), this limitation is due to frameworks being generic and because the design guidelines provided are not context-specific (Sari et al., 2020; Oyibo, 2021). Designers employing this framework must deal with the complexity of identifying context-specific design features.
- Lastly, all the frameworks ignored other important aspects of a PT (Sari et al., 2020; Oyibo, 2021). Designers need to be aware of the limitations of the desired behaviour, understand the problems surrounding the domain for which the PT is designed (West et al., 2020), and,

further, be aware of the technologies suited to the target user and domain. None of these aspects are addressed in existing frameworks.

Taking into account these problems, researchers have clamoured for context-specific PT frameworks (Choe et al., 2011; Leite et al., 2018; Murillo-Munoz et al., 2018; Murillo-Muñoz et al., 2021), which would provide a more detailed level of design guidelines for specific contexts. Currently, no existing framework focuses on the design of PT for motivating young female students in Nigeria to enrol in STEM (Murillo-Munoz et al., 2018). Such a framework is essential to address the peculiarities surrounding female students' enrolment in STEM.

Thus, this study purports to develop a PET4STEM framework for a persuasive educational technology-based tool using the design science research (DSR) approach for designers to use in designing PT for motivating young Nigerian female students to enrol in STEM. In this regard, the research contributes to the design science research body of knowledge through a framework design.

1.4 RESEARCH AIM AND OBJECTIVES

This study primarily aims to develop a PET-based framework for motivating junior secondary school female students in Nigeria to enrol in STEM. This research examined three main objectives:

1. To identify barriers affecting the enrolment into STEM classes of junior secondary school female students in Nigeria.

2. To explore the available persuasive strategies that would be effective in motivating junior secondary school female students in Nigeria to enrol in STEM.

3. To develop a PET4STEM framework for a persuasive educational technology-based tool aimed at motivating junior secondary school female students in Nigeria to enrol in STEM classes when they transition to secondary school.

1.5 RESEARCH QUESTIONS

The main research question is: How can a PET-based framework for motivating junior secondary school female students in Nigeria to enrol into STEM be designed?

The sub-research questions based on the main research questions are:

1. What factors influence enrolment in STEM classes by junior secondary school female students in Nigeria?

2. What persuasive strategies could be effective in motivating junior secondary school female students in Nigeria to enrol in STEM classes?

3. How can a PET4STEM framework for a persuasive educational technology-based tool for motivating junior secondary school female students in Nigeria to enrol into STEM classes when they transition to secondary school be designed?

Identifying the factors influencing female students' enrolment in STEM would help designers ascertain which factors to focus on when motivating female students. Further, identifying what persuasive strategies could be effective in motivating female students would help designers determine which strategies to employ.

1.6 SCOPE OF THE STUDY

The scope of the study is recognised as follows:

- The school subjects this study is concerned with are physics, chemistry, biology, agricultural science, technical drawing, metalwork, woodwork, electronics, mathematics and introduction to computer science. These subjects are considered STEM in Nigerian secondary schools (Federal Ministry of Education, 2019).
- The study focused on female students in junior secondary classes in Nigeria. Female students in senior secondary classes were not included in the study because at the senior secondary level they have already chosen their professions. Second, because there is a paucity of research targeted at female students in junior secondary classes.
- The female students were sampled from three different schools in Kano state in Nigeria. The reason for choosing Kano was that it is the most socially diverse state in Nigeria (National Bureau of Statistics, 2019) and thus is a good representation of Nigeria. However, the qualitative approach of this study did not aim to select a representative sample for broad generalisation but rather was an empirical data collection to gain deeper insight into the situation from a new area not studied before to enable the conceptualised idea or identified components to be further explored by similar case studies. Polit and Beck, (2010) assert that rather than pursuing a large sample size, qualitative research rides

on gathering data from a small number of information-rich participants who can illuminate the phenomenon under study.

- The framework developed focused on providing designers with the different components relevant to designing a PT for motivating female students to enrol in STEM and how designers can implement the different elements of each component. These components are the persuasion component, the pedagogical component, the technology component, and the component that informs designers of the factors influencing enrolment into STEM.

1.7 RESEARCH METHODOLOGY

Every research is based on a well-defined philosophical stance that depicts how a researcher perceives reality and how they make sense of the assumed reality. The researcher's philosophical viewpoint underpins their choice of research approach, strategy, data collection technique and data analysis procedure. The next subsection provides a brief overview of the research methodology. the methodology was further expanded on in Chapter 5.

1.7.1 Research Paradigm

The ontological stance that this study aligns with is constructivism. Constructivism is a paradigm that asserts that reality is dynamic because it is socially constructed. The reason for choosing this philosophical stance was because the researcher assumed all female students had different lived experiences, and, therefore, the factors influencing their choice of profession and the strategies to motivate them would differ. This assumption implies that the factors influencing their choice of profession and the strategies to motivate them should not be investigated through scientific methods, as with the investigation of physical phenomena that yield pure data and facts intolerant of human interpretations. In addition, the epistemological stance of this study is interpretivism, which is concerned with understanding the world from a subjective point of view. The reason for choosing this philosophical stance was that the researcher assumed an open-ended investigation technique would provide a more in-depth understanding of the factors influencing female students' choice of profession and how to motivate them to enrol in STEM pathways.

1.7.2 Research Approach

The research approach used is the exploratory inductive approach because it is an approach that does not depend on pre-assumptions. In this study, conclusions were drawn from the collected data. Although previous studies have investigated factors affecting enrolment in STEM disciplines and how to motivate female students to enrol in STEM disciplines, their findings might not necessarily agree with those of the current study's audience at the time of this research. Hence, the research delved into the natural setting of its audience to allow participants to relay their reality based on their narrative. The researcher conducted interviews with three categories of participants: students, STEM teachers and STEM professionals, and performed content analysis to analyse the resultant data.

1.7.3 Research Strategy

The study relied upon the design science research (DSR) strategy to investigate the design of the PET4STEM framework. DSR focuses on the creation of socio-technical artifacts, such as decision support systems, modelling tools, governance strategies and interventions to change existing societal circumstances into that which are sought after (Perna, 2017; Brocke et al., 2020; Evon et al., 2020). It is worth stating that the DSR can serve either as a strategy or a theory. As a method, it provides guidelines for creating, improving and evaluating IT artifacts, which can be either constructs, models, methods or instantiations. As a theory, DSR serves as the philosophical basis for the research paradigm, just like positivism, interpretivism and critical research (Weber, 2010). In this study, DSR served as a strategy to provide guidelines for creating the PET4STEM framework.

The rationale for choosing DSR as a strategy is its rigorous iteration phases that ensure the framework is redefined several times until valuable, rigorous and publishable artifacts are produced (Brocke et al., 2020). A framework that provides other researchers with design guidelines concerning an educational problem needs to go through a series of design, enactment, analysis, and redesign cycles before a final output can be produced. Several studies concerned with the design of constructs, models, methods or instantiations in the Information Systems (IS) field have employed DSR because it provides an explicit and transparent process that ensures design rigour. Chapter 5 provides a more detailed examination of the DSR methodology, including a discussion of how the study followed the method to design the PRT4STEM framework.

1.7.4 Data Collection and Analysis

The study recruited students, teachers and STEM practitioners through convenience sampling, purposive sampling and key informant sampling. Convenience sampling was used to select the three secondary schools, and purposive sampling was used to select fifteen junior secondary school girls and five teachers from the three schools. Lastly, key informant sampling was used to sample five STEM professionals from different organisations. The researcher obtained students', lecturers' and STEM professionals' responses through face-to-face interviews and a focus group session and analysed the resultant data qualitatively.

1.7.5 Justification for Sample Size

Justification for the adequacy of the sample size (n=25 for framework development and n=32 for framework evaluation) is based on the recommendation of Marshall et al. (2013). Marshall et al. (2013) examined 81 publications from leading information system journals and recommended three criteria for determining the adequacy of sample size in qualitative research: (1) sample size must be based on suggestions from a qualitative methodologist; (2) sample size must match those of prior research in the same field, with similar research problems and methodology; and (3) data analysis must demonstrate that data saturation has been reached. This study met all three criteria. First, the sample size was based on references from qualitative research methodologists (Shenton, 2004; Bretz, 2008; Holbrook et al., 2007; & Malhotra, 2010). For instance, Morse (2000), recommends six to ten interviewees for qualitative research, Denzin and Lincoln (1994) recommend six interviewees and Creswell (2007) recommends three to five interviewees. Second, prior similar studies in information systems have also used similar sample sizes. For instance, Angkananon et al. (2013) used three experts to validate the framework they had designed to enhance technology interaction. Aagaard (2015) used six teachers and fourteen students to investigate the distractions caused by educational technologies in classrooms; and Tshuma (2018) used nine interviewees to investigate the use of educational technologies in a university.

Lastly, as regards data saturation, when the researcher approached the schools to obtain consent from the school principals, the news spread around the school very quickly. Many students and teachers showed interest in participating. Students would approach the school principals' offices to indicate their interest in participating, even while the principal was still scrutinising the consent form. The teachers later disclosed that the students were excited to take part in the research because a female researcher was involved. Eventually, 24 students and 11 teachers consented and were interviewed for the study. After interviewing the eleventh student, the responses became repetitive; the remaining students provided no substantial information. However, the students still had to be interviewed for data saturation to be reached. The additional nine participants did not give any new information. The same happened during the interviews with the STEM teachers and STEM experts. After the third teacher and third STEM expert, no new insight emerged. Nielsen and Landauer (1993) also argue that after the fifth expert, no new information is derived from an interview session, thus justifying the adequacy of the sample size used in the present study.

1.7.6 Ethical Consideration

The study obtained ethical clearance from the Research Ethics Committee of the College of Science, Engineering and Technology (CSET) of the University of South Africa (UNISA), which approved before data collection. Ethics clearance committees ensure that data are collected in a way that does not cause any discomfort or harm to research participants (Tusino & Furfaro, 2022). The participants were informed about the purpose of the study, and they provided consent to participate. The students' parents and the school principals also consented. They were all in support of the study.

1.8 RESEARCH CONTRIBUTION

The contributions of this research to the body of knowledge include the following.

1. At a theoretical level, the study develops a new framework, informed by the DSR approach, that provides information regarding the essential components PT designers should consider when designing PTs for promoting STEM enrolment by junior secondary school female students in Nigeria. To the knowledge of the researcher, no study in Nigeria has developed a framework for the design of PTs for promoting such STEM enrolment.
2. At an empirical level, the study establishes the factors influencing junior secondary school female students' enrolment in STEM classes. Limited studies have empirically investigated the factors affecting the enrolment of female students in junior secondary schools in STEM disciplines. The results of this study can serve as a strong empirical base for future studies targeted at this population.

3. The third contribution of the study is providing persuasive strategies that can be employed to mitigate female students' negative perceptions about STEM subjects. These strategies can be used by schoolteachers, parents and researchers not developing a PT.

1.9 THESIS STRUCTURE

The study comprises seven chapters and is divided into three phases, as shown in Figure 1.1. Chapters 1, 2 and 3 present the motivation for the study; Chapters 4, 5 and 6 present the approach used to address the concerns of the study, while Chapter 7 presents the outcome.

Chapter 1: Introduction and Background

This chapter introduced the study. It established the context of the research and the problem, scope, research methodology, expected contribution and structure of the research.

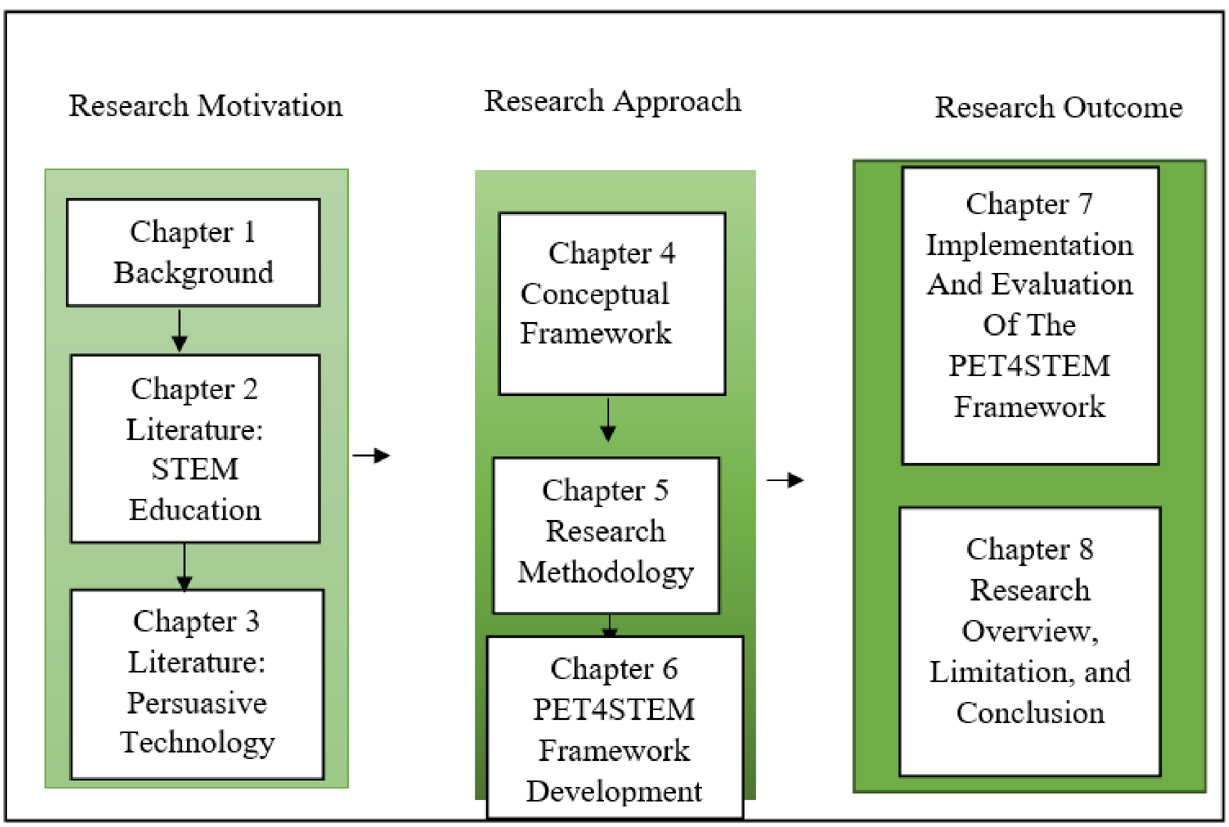

Figure 1. 1: Thesis Structure

Chapter 2: Literature Review on STEM Education

This chapter addresses the first research question of the study. It starts by presenting literature that indicates the gender gap in STEM disciplines across secondary and university school levels in Nigeria. It then discusses females' educational motivation using literature from different parts of the globe to understand females' career choice-making. The chapter then reviewed well-established theories on enrolment behaviour to further understand female students' career decision-making process. Then a literature review was conducted on empirical works to identify factors that influence female students' enrolment in STEM disciplines. The chapter concludes with key constructs that influence females' professional choices.

Chapter 3: Literature Review on Persuasive Technology

Chapter 3 addresses the second research question of the study. This chapter starts by discussing the concept of PT and where it fits in the education domain. It then discusses the different application areas of PT and its potential at motivating junior secondary school female students to enrol in STEM disciplines. The chapter then reviews existing frameworks for designing PT and the different studies that employed the frameworks to identify what persuasive design strategies were employed. This led to a discussion of the limitations of the existing frameworks and how the study intends to address the limitations.

Chapter 4: Conceptual Framework

This chapter presents the conceptual framework based on the literature reviews conducted in Chapters 2 and 3. It presents the key components that a PET4STEM framework needs to achieve its aim and objectives.

Chapter 5: Research Methodology

This chapter describes how the research was conducted. The research paradigm, research strategy, research approach, data collection, and data analysis techniques used were described and justified.

Chapter 6: Development of the Persuasive Educational Technology Framework

Chapter 6 addresses the third research question of the study. It presents the findings and the interpretation of the data that was collected. It then presents the final PET4STEM framework.

Chapter 7: Implementation and Evaluation of the PET4STEM Framework

This chapter reports the implementation and evaluation of the PET4STEM framework.

Chapter 8: Research Contribution, Conclusion, and Future Work.

This chapter presents the contribution of the framework. It also concludes the study and provides direction for future work.

1.10 SUMMARY

This chapter discussed the low number of female students taking STEM pathways in school and the need to have more females in STEM professions to fill the increasing demand for skills in Nigeria. This was followed by a discussion on the use of PT as a tool to motivate junior secondary school girls in Nigeria to enrol in STEM disciplines. The need for a context-specific framework that designers can follow to design their PT was then established. The chapter concludes by discussing the potential contribution that the study brings to Design Science Research, the Persuasive Technology community, and STEM educators.

CHAPTER 2: LITERATURE REVIEW ON STEM EDUCATION

2.1 INTRODUCTION

The literature review in this study is divided into two chapters (Chapters 2 and 3) to address the main concepts of the study comprehensively. This chapter details a literature review on STEM education, while Chapter 3 is a literature review on persuasive technology.

The purpose of this chapter is to understand why females choose non-STEM professions over STEM professions and identify shortfalls in previous studies that focused on motivating females to pursue STEM professions for the present study to determine how to address such deficits. This was accomplished by reviewing theoretical and empirical literature. The researcher reviewed existing enrolment behaviour theories to understand how individuals make career decisions and examined empirical literature focusing on factors influencing female students' enrolment in STEM disciplines to ascertain what had been communicated about factors influencing female students' enrolment in STEM disciplines. Lastly, the study reviewed the literature on motivating women to pursue STEM professions.

The rest of the chapter is organised as follows: Section 2.2 defines what the acronym STEM means in the context of this study to establish the subjects that are the focus of the study. Sections 2.3 and 2.4 review the statistics on the gender gap in STEM fields to support the study's claims about the gender gap in STEM discipline. Section 2.5 provides an understanding of women's educational motivations using Maslow's hierarchy of needs as a theoretical framework. Section 2.6 considers theories on enrolment behaviour to understand factors influencing female students' enrolment in STEM disciplines, and Section 2.7 reviews the empirical findings regarding such factors. Section 2.8 reviews the literature on motivating females to enrol in STEM disciplines, and Section 2.7 summarises the chapter.

2.2 WHAT IS STEM

STEM is an abbreviation for a group of educational fields related to science. The US National Science Foundation (NSF) in the early 1990s introduced the concept in response to a growing desire to empower students with the necessary skills for the 21st century. However, there is disagreement about the fields that should be considered STEM. The United States (US) Immigration and Customs Enforcement Department, for example, excludes social science fields from their definition of STEM. As a result, when making visa decisions for foreign professional workers in STEM fields, fields such as political science and psychology are not considered STEM fields. On the other hand, federal agencies, such as NASA and the Federal Ministry of Education in Nigeria, include social science fields in STEM (White, 2014; Federal Ministry of Education, 2022). Another issue is the variance based on the educational level at which the subjects are taught (White, 2014; Aquino, 2023). STEM, for example, is limited to mathematics and basic science in elementary school but becomes more sophisticated in high school and thus includes more subjects. STEM becomes more specialised as education progresses; therefore, its definition shifts.

Due to these issues, there are no universally accepted subjects grouped under the acronym STEM. (Darling-Hammond et al., 2020a). Researchers and educators define STEM subjects based on their research contexts (White, 2014; Hurk et al., 2019; Yun, 2023). According to Hurk et al. (2019), the definition of the acronym STEM should be specific to an empirical study provided the original concept of STEM, which emphasises the application of knowledge to real-life situations, is maintained.

2.2.1 STEM in the Context of the Study

In this study, the subjects referred to as STEM are clarified through the four broad disciplines in the acronym STEM.

1. Science: Science comprises many fields categorised into two branches. The one branch is social sciences, which contains subjects like sociology, political science, psychology, archaeology and anthropology. The other is natural science, incorporating subjects like biology, physics, chemistry, astronomy, human anatomy, etc. In Nigerian secondary schools, science in STEM refers to only a handful of these subjects because of the level at which these subjects are taught in secondary school. Subjects like psychology, human anatomy, sociology, political science and anthropology are not taught in secondary schools; rather, the foundations of these science subjects are taught. The STEM subjects taught are physics, chemistry, biology, geography and economics. These subjects lay the foundation for the knowledge and skills required to succeed in higher science disciplines (Federal Ministry of Education, 2023).

2. Technology and Engineering: At a more advanced level of education, like at university, technology and engineering in STEM are two distinct bodies of knowledge. The technology courses include computer science, construction technology, computer technology and information systems, while engineering includes chemical, electrical, mechanical and civil engineering. At the secondary school level in Nigeria, these two fields overlap because the foundations of these fields are interrelated, and the basics are taught in secondary school (Blake et al., 2014; Kiernan et al., 2023). The subjects representing technology and engineering in the context of the present study are introduction to computer science, electronics, technical drawing, woodwork, and metalwork (Federal Ministry of Education, 2023).

3. Mathematics: Mathematics comprises a body of knowledge concerned with the study of numbers, shapes, quantity and their relativity using special notations (Bybee, 2010). Branches of mathematics include algebra, calculus, arithmetic, geometry and trigonometry. These branches are taught as topics in general mathematics in Nigerian secondary schools; hence, in the context of this study, mathematics in STEM refers to general mathematics taught in secondary schools (Federal Ministry of Education, 2023).

2.3 THE GENDER GAP IN STEM DISCIPLINES ACROSS THE GLOBE

The gender disparity in enrolment into STEM fields is evident in research findings from many countries across the world. However, the numbers vary between countries, with some countries having fairer representation than others, which also varies between fields, with some fields having fairer representation than others (UNESCO, 2015; Mukhwana et al., 2020). For example, as regards variation between countries, the United States and countries in the Caribbean region have a more equitable representation of women in STEM at both school and career levels. For example, in the Caribbean region, female students dominate STEM disciplines in universities by 75% and constitute 45.4% of researchers in STEM (UNESCO, 2015; Mukhwana et al., 2020). This is not the case in other countries like Japan, 15%; Korea, 18%; India, 15%; Ethiopia, 13%; and Chad, 5%; falling to single digits in Nepal at 1%.

Regarding variations between fields globally, of the number of students enrolled in ICT, only three per cent are female; in mathematics and statistics, it is five per cent; and in engineering, construction and manufacturing, it is eight per cent. This is also the case within countries. In the UK, for example, in engineering and ICT, female representation is 19%; in mathematics, it is 37%; and in physics, it is 39% (STEM Women, 2020). Still, within a country, there is a difference in female representation between levels. Female representation in some countries continues to drop as women advance up levels. For example, in Canada, women constitute 44% of STEM undergraduate students, but as they advance to career levels, their numbers drop to 32% (Wall, 2019; Chang & Yen, 2023).

This data is corroborated by a study conducted at the University of British Colombia in Canada, which revealed that only one in five women in the undergraduate computer science program will graduate as a computer scientist (Wall, 2019). Similarly, in the United Kingdom, women represent 38.6% of STEM students at university, but at the career level, their representation falls to 32% (UNESCO Institute of Statistics, 2018). In Japan, women comprise 25% of STEM students at the university, but at the career level, their representation also falls to as low as 15%. Sub-Saharan African countries share these numbers, with the disparity higher in some countries than others. In Morocco, women constitute 45% of STEM students at colleges and universities, while STEM researchers comprise 30%. In Lesotho, women constitute 23% of students in STEM fields at colleges and universities and 31% of STEM researchers (UNESCO Institute of Statistics, 2018). Nevertheless, there is no discernible difference in female representation from one level to another in some countries. A case in point is South Africa, where females comprise 42% of students in STEM fields at colleges and universities and 43.7% of STEM researchers (Mukhwana et al., 2020; The World Bank, 2020). This data provides a general idea of the disparity in different countries. Subsequently, this study focuses on the country, which is the main concern of the study, Nigeria.

2.4 THE GENDER GAP IN STEM DISCIPLINES IN NIGERIA

Nigeria is among the lowest performing nations in sub-Saharan Africa on all levels when it comes to enrolment into STEM disciplines by females. Data from the National Bureau of Statistics (2019) reveal that 22% of STEM students at colleges and universities are female, while only 17% of STEM researchers are female. This section presents data on three levels of education where the disparity in STEM is noticeable to exhibit a robust picture of this disparity: (1) STEM students at senior secondary school, (2) STEM students at undergraduate level, and (3) STEM students at postgraduate level.

Comprehensive and reliable data on the disparity in STEM disciplines at the secondary school level is not readily available in Nigeria, signifying how much researchers have ignored this population and emphasising the need for researchers to direct their attention to this group. However, two reliable, although dated, studies (Nnaka & Anaekwe, 2006; Egun & Tibi, 2010) investigated students' enrolment rates in STEM at the secondary school level; which confirm that fewer female than male students take STEM subjects at the secondary school level. Table 2.1 and Table 2.2 show the gender parity index (GPI) in STEM disciplines at the senior secondary level.

Table 2. 1: Enrolment rate of students in STEM subjects the 2006 national examination conducted in Nigeria for secondary school students.

Subjects	Males	Females	Gender Parity Index
Chemistry	71709	44542	0.621
Physics	64567	31969	0.495
Biology	156673	128314	0.819
Health Science	3029	2767	0.914
Agricultural Science	134951	86418	0.640

Source:(Egun & Tibi, 2010)

GPI is a socioeconomic index designed to measure the relative participation of female and male students in a subject. The closer the value of GPI is to one (1) signifies equality between the genders. From Table 2.1, it can be deduced that there is a disparity in STEM disciplines at the secondary school level, with some subjects having a higher disparity than others. Physics, for instance, has a disparity of 0.495, while health science has a disparity of 0.914.

Table 2. 2: Enrolment rate of students in STEM education subjects in the 2006 national examination conducted in Nigeria for secondary school students.

Subject	Total Students	Male	Female	Gender Parity Index
Further maths	18557	14732	3825	0.259
Electronics	245	200	45	0.225
Metalworks	570	562	8	0.014

Woodworks	499	488	11	0.023
Technical Drawing	7490	6462	1028	0.159
Physics	265262	158402	106860	0.675
Auto Mechanics	169	166	3	0.018
Applied Electricity	389	337	52	0.1543
Chemistry	269774	159333	110241	0.6910
Building Construction	200	178	22	0.1234
General Mathematics	832689	446907	385782	0.862
Agricultural Science	656599	369893	286706	0.775
Biology	821966	439388	382608	0.871
Clothing and Textile	541	15	436	29.067
Food and Nutrition	16903	1196	15707	13.133
Home Economics	11066	475	10591	22.291

Source: (Nnaka & Anaekwe, 2006).

Tables 2.1 and Table 2.2 also indicate that some subjects show a higher disparity than others: subjects such as metalwork (GPI ≈ 0.0142), auto mechanics (GPI ≈ 0.0181), and further mathematics (GPI ≈ 0.259) have a higher disparity than subjects such as clothing and textile (GPI ≈ 29.067), food and nutrition (GPI ≈ 13.133), and home economics (GPI ≈ 22.297). At the tertiary level, the disparity is even direr. The worrying disparity is already evident in data from 1988. Table 2.3 is data from a study conducted by Adeyemi and Akpotu (2004), who reported on the enrolment pattern in three STEM faculties in Nigerian universities.

Table 2. 3: Enrolment of students in STEM education faculties in Nigerian universities between the 1988/1989 and 1996/1997 academic sessions.

	Faculty of Engineering			**Faculty of Medicine**			**Faculty of Science**		
Year	**M**	**F**	**D**	**M**	**F**	**D**	**M**	**F**	**D**
88/89	5892	545	0.092	3716	925	0.249	14705	3928	0.267
89/90	5600	524	0.094	3983	963	0.242	15260	3887	0.255
90/91	7325	724	0.099	3979	208	0.052	18252	4829	0.265
91/92	8708	341	0.039	5087	1478	0.290	20770	6158	0.296
92/93	8920	626	0.070	12479	2664	0.213	8920	626	0.070
93/94	9887	465	0.047	12543	2258	0.180	9887	465	0.047
95/96	11291	1566	0.139	6463	2588	0.400	11292	1566	0.139
96/97	5196	509	0.098	11642	5056	0.434	5198	509	0.098
Key M=Male, F=Female, D=Disparity									

Source:(Adeyemi & Akpotu, 2004)

It is apparent in this table that there is a disparity in all three faculties, but the disparity is higher in the Faculty of Engineering. Furthermore, there is a steady increment in enrolment of male students across all three faculties while that of female students fluctuates. The increase for males is relatively higher than that of females. In the Faculty of Engineering, the mean increment for males is 1,369, while the mean increment for females is 528. In the Faculty of Medicine, the mean increment for males is 3,436, while the mean increment for females is 1,021. In the Faculty of Science, the mean increment for males is 1,970, while the mean increment for females is 1,124.

Aguele and Agwagah (2007) provide another set of data on students' enrolment in the technology and science faculties over four years across twelve universities in Nigeria. Of the 35,279 students enrolled in the Faculty of Technology, only 7,411 were female, that is, 21% of the students. In the Faculty of Science, only 12,974 of the 43,684 students were female, i.e., approximately 30%.

Table 2. 4: Student enrolment in technology and science education faculties between the 1998/1999 to 2001/2002 academic sessions across 12 universities in Nigeria.

Year	Faculty of Technology			Faculty of Science		
	Male	Female	Disparity	Male	Female	Disparity
1998/1999	4830	1011	0.021	4000	1900	0.475
1999/2000	7800	1500	0.19	6800	3500	0.515
2000/2001	6800	3500	0.515	9460	3924	0.415
2001/2002	8468	1400	0.165	10450	3650	0.349

Source: (Aguele & Agwagah, 2007)

Popoola et al. (2018) investigated a single university to obtain a more in-depth view of this disparity. Again, the disparity persists with a pattern reminiscent of previous data. The authors noted that between the 2002 and 2009 academic sessions at Covenant University, Nigeria, only 712 of the 2,649 students admitted into the engineering faculty were female, approximately 27%.

In more recent studies, Abdullahi et al. (2019) also indicated that in the 2014/2015 academic session at Kano State University of Technology, only one of the 324 students admitted into the engineering faculty was female. Table 2.5 presents a summary of the findings by Abdullahi et al. (2019).

Table 2. 5: Students enrolment in STEM disciplines at Kano State University of Science and Technology, Wudil, Nigeria (KUST). Academic session 2014/2015.

Courses	Male	Female	Gender Parity Index
Mathematics	131	2	0.015
Physics	112	1	0.009
Chemistry	67	12	0.179
Biology	82	32	0.390
Mechanical Engineering	324	1	0.003

www.kustwudil.edu.ng 2014/2015 as cited in (Abdullahi et al. (2019)

This disparity persists as students progress into graduate school. Tables 2.6 and 2.7 display the statistics of students' enrolment in STEM disciplines at Bayero University Kano, Nigeria. These records also reveal the increasingly limited participation of females in STEM disciplines.

Table 2. 6: Students enrolled in the master's degree program at Bayero University Kano, Nigeria (BUK). Academic session 2019/2020

Faculties	Male	%	Female	%	Gender Parity Index
Faculty of Computing	329	88	46	12	0.139
Faculty of Engineering	84	89	10	11	0.119
Faculty of Physical Science	193	82	42	18	0.218
Faculty of Life science	40	49	41	51	1.025

Source: www.buk.edu.ng

Table 2. 7: Students enrolled in the doctoral degree program at Bayero University Kano, Nigeria (BUK). 2019/2020 academic session.

Faculties	Male	%	Female	%	Gender Parity Index
Faculty of Engineering	32	91	3	9	0.094
Faculty of Applied Science	77	87	12	13	0.155
Faculty of Life Sciences	73	61	47	39	0.642

Source: www.buk.edu.ng

This data displays the gender disparity within the STEM fields. It also shows that some STEM subjects have a higher disparity than others, a pattern that has been identified around the globe (UNESCO, 2015; Mukhwana et al., 2020). These figures are alarming given the increasing number of female students enrolling in schools (National Bureau of Statistics, 2019a).

2.4.1 The Benefits of More Women In STEM

The need for more women in STEM goes beyond gender gap quotas: the wider community stands to benefit greatly from more women in STEM. Further benefits of having more women in STEM are discussed below.

1. Promoting more "gendered innovations": The term "Gendered innovations" was coined in 2015 by Schiebinger (2021) when she started to question the relevance of an innovation that did not consider the female gender. Gendered innovations are *"*processes that integrate sex and gender analysis into all phases of basic and applied research to assure excellence and quality in outcomes*"* (Schiebinger, 2021 p.1). Over the years, there has been claim that researchers often overlook the gender of their subjects when conducting research, ignoring the fact that neglecting gender as a factor can limit the benefit of the research to the public (Schiebinger, 2021). For example, when the seat belt was invented, it was designed entirely on the physical features of men, so when it was made available for public use, several women and children were reported to die whenever they were involved in accidents (Imafidon, 2020). This was attributed to the fact that their physicality was not considered during the seat belt design, so it did not serve as a safety equipment for them (Imafidon, 2020).

Imafidon (2020) also highlighted the very recent case of *Fitbit* coming under criticism for not allowing women to record a menstrual period of over 7 days. Imafidon (2020) claimed that the application was designed with the belief that the length of the female menstrual cycle is seven days. If more women were consulted during the design phase, this would probably not have been the case. There is huge advocacy for the inclusion of women as research subjects to enhance scientific discoveries. For today's and future science to be as safe and impactful as projected, gender needs to be a significant factor in research. This can be more achievable if women make their presence more felt in the STEM community. With more women in STEM, researchers will be compelled to put the female and male genders into equal consideration.

2. Promoting diverse and unique perspectives to research: As STEM research soars in advancement, more women can promote diversity and uniqueness in STEM research and its outcomes. Both genders can bring their unique perspective into understanding both the scientific and non-scientific aspects of research. For example, Ali-Eunus et al., (2020) lead the development of an application inspired by her experience as a woman growing up in Bangladesh. She explained that women face harassment on the streets of Bangladesh daily but are always embarrassed to share their experiences. As a result, the application was developed for women to share their experiences and keep their identities anonymous. The application suggests safe routes to its users based on the experiences of other users.

3. Improving the Socio-Economic Status of women: Socio-economic status (SES) goes beyond income; it is a correlate of several components of subjective well-being, including psychological health, emotional health, and satisfaction with life. This implies that the quality of life and privileges individuals enjoy within their society depend on their SES. The SES of most women in Nigeria is very low; about 46% of Nigeria's informal labour force is made up of women (International Labour Organization, 2022). This sector has become a "haven" for women because it requires little or no educational qualification for entry. This is the case in most countries in Africa; Around 19.5 million women in sub-Saharan Africa were involved in the informal labour force in 2020 (International Labour Organization, 2022). Fapohunda (2022) attributed the huge number of women in the informal labour force to their limited access to education, land, technology, and credit.

Withal, the low SES of women can rub off on their children. For example, research shows that children whose mothers have low SES develop learning skills slower than children whose mothers have high SES (Morgan et al., 2019). Because they are less likely to be exposed to activities that promote the development of fundamental literacy and numeracy skills. STEM offers far more skills than the skills most women in Nigeria currently have. If equipped with STEM skills women will be exposed to more decent jobs which means better earnings and higher SES. In the United States, for instance, the average salary per annum is $42,980, while the salary of a computer programmer with a bachelor's degree is $71,000 (International Labour Organization, 2022).

4. Boosting overall economic growth and development: In addition to improving the SES of women, more women in STEM careers have the potential to strengthen the Nigerian economy overall. Countries such as the United States and Germany have strategic programs to improve economic outcomes in their countries through STEM degree attainment (International Labour Organization, 2022).

2.5 UNDERSTANDING WOMEN'S EDUCATIONAL MOTIVATION

To understand why women choose certain career paths over others, the researcher first tried to understand why they go to school in the first place, hoping that if their reasons for attending school are understood, their goals and perceived career paths leading to achieving such goals would be understood. This research employs the needs hierarchy theory as a guiding framework together with empirical studies towards attaining such understanding. The needs hierarchy theory, developed by Abraham Maslow in the 1940s, is a well-respected theory that explains people's motivation for pursuing different goals in life. The section reviews previous studies investigating women's educational motivation and analyses their findings using Maslow's needs theory (1943). The next subsection discusses Maslow's theory.

2.5.1 Maslow's Needs Hierarchy

Maslow's needs theory ranks human needs in order of priority and asserts that if the most basic needs are not fulfilled, then the desire to pursue more advanced needs might not arise. These needs are explained below, starting from the most basic.

1. Physiological needs: These needs are considered the major motivation for people; if these needs are not met; People will not be motivated to fulfil the next need in the hierarchy. These needs include the need for air to breathe, water to drink and food to eat. If these needs are met, then individuals begin to seek the following requirements in the hierarchy.

2. Safety needs: This refers to the need to be secure. Once people have satisfied their physiological needs, they start seeking the need to be protected and feel safe from any physical and emotional harm, force or limitations. When a person no longer has any physical or emotional fear of their environment, the motivation to pursue the next need in the hierarchy is heightened.

3. Belonging and love needs: These needs include the need to be loved and accepted by others and to feel comfortable around them. People seek friendship, family and sexual intimacy once they feel safe. When the need for belonging and love is not fulfilled, it hinders the motivation to seek the next need in the hierarchy.

4. Esteem: This level includes the need for self-confidence, self-worth, independence, status, recognition, respect and appreciation by others. When people feel loved and have a sense of belonging in an environment, they want to impact society and want their contributions to be recognised and appreciated. When the need for self-esteem is satisfied, the motivation to pursue the next need in the hierarchy is aroused.

5. Self-actualisation: The highest need in the hierarchy is the desire for people to realise themselves, the tendency to manifest in what is potentially inherent in them. Most individuals desire to be the best they can become; unfortunately, failure to meet lower-level needs frequently hinders progress. Figure 2.1 is a diagrammatical representation of Maslow's hierarchy of needs.

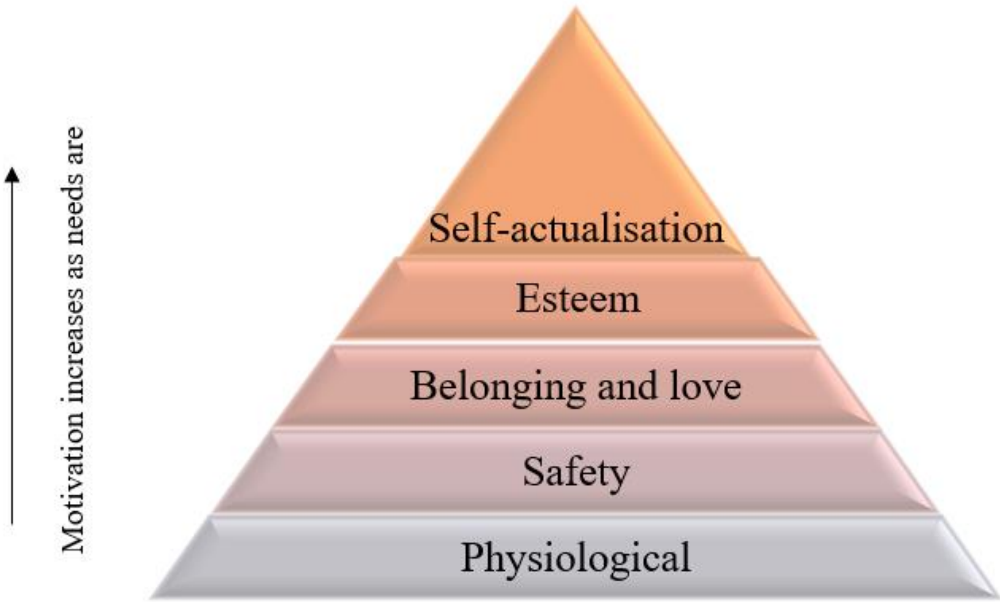

Figure 2. 1: Maslow's hierarchy of needs (Maslow, 1943).

The theorist admits that this hierarchy does not apply to everyone; some individuals are satisfied with meeting their esteem needs. He also admits that a need does not have to be 100 per cent satisfied before the motivation for the next need is triggered. How do these needs explain the female choice of a career path? The upcoming subsection discusses studies on women's educational motivation along with their implications for women's choices of career paths.

2.5.2 Review of Studies on Women's Educational Motivation

This sub-section looks at studies that has investigated women's educational motivation. This is relevant because if their reasons for attending school are recognized, their aspirations and perceived career paths leading to reaching those goals might be understood. Some studies point to interesting reasons why women go to school, which can be linked to the needs in the Maslow hierarchy and used to infer their choice of career paths.

A qualitative study in India reveals noteworthy motivations for women's educational pursuits (Bunter, 2005). The study was conducted among women in Kerala, India, a state with a consistently higher number of female students attending school, compared to other states in India. The psychological benefit they gained from the interaction with others in school was a motivating factor. According to the students, it was depressing to stay home and not go to school. This motivation can be linked to the third need in Maslow's hierarchy, the need for belonging. The wish to be more marketable for marriage was also a motive in that study. The women felt that being highly educated attracted a highly educated partner, which elevated their status in society. The dowry owed to their husbands' families was consequently reduced.

The findings of Bunter (2005) are consistent with Murickan (2002), whose research among 400 couples in Kerala found that the men preferred educated girls. The men explained that being educated indicated the potential for 'white-collar' jobs, which meant more income for the family. This can be interpreted as the need to be appreciated by society, which can be linked to the need for esteem under Maslow's theory. The women perceived that society preferred and respected educated women and that they wanted to experience that status and respect.

Another study among 1147 female secondary school students in the Philippines revealed similar motivations (King et al., 2012). The students' desire for societal obligations and conforming to social expectations drove their motivation. They believed they were obliged to take care of their parents and younger siblings and prosper at school to accomplish these objectives. Some of these obligations included supporting their parents financially and representing their families at social events. The female students sought good employment to gain higher societal status, which would, in turn, benefit their families' reputations. They also expressed the need for social interaction with other school students. This finding is supported by a more recent study among 848 Filipino female secondary school students, where the need to fulfil social responsibilities and to gain social status (King, 2016) were their motives. Again, the presented motivations from these studies can be linked to the need to belong and the need for esteem in Maslow's hierarchy.

An equivalent motivation was discovered in a qualitative study among secondary school females in Tanzania. Melin (2013) found that women wanted to provide for their present and future families and attract educated partners. They also desired to make their own decisions and be in control of their lives. School was also where they formed social connections, which further motivated the girls. Similarly, in Nigeria, women were motivated by the need to obtain employment to support their families financially (Shamsideen, 2015). This was also found as the educational motivation of Nigerian women in Obeta et al. (2003). An older study among female Nigerians identified finance and prestige as the most important factors motivating women to further their education (Nevadomsky, 1981). The women wanted total control over their personal lives and the right to actively participate in decision making in their communities. Again, the presented motivations in the above-mentioned studies can be categorised under the need for belonging and esteem in Maslow's hierarchy. Cross & Madson (1997) argue that women have a stronger relational self than men, which may suggest their inclination towards social goals and values. This argument is supported by existing research indicating that women attach more value to meeting family and societal obligations than men (Anderman & Midgley, 1997; Fuligni & Zhang, 2004).

Some studies from other regions of the world corroborate the motivations found in these studies. For instance, Jozefowicz et al. (1993 p.16) report in their study among 1,642 predominantly white students in Michigan, USA, that "females valued making occupational sacrifices for their family" as well as "having jobs that allow them to help others and do something worthwhile for society" more than men. In another study on educational motivation among individuals in the United Kingdom, Chevalier (2002) reports that women are more concerned about the social relevance of their jobs compared to men. They indicated that they preferred careers that allowed them to interact directly and feel the impact of the interaction with the people around them.

A study by Hijzen et al. (2006) among a Dutch population also found women's educational motivation socially grounded, which was the same in a study by Cerinsek et al. (2013) among Slovenian female students, finding a preference for careers involving empathetic and interpersonal activities, such as helping others, contributing to society and protecting the environment. In a more recent cross-cultural study on school motivation among individuals from Australia, The Netherlands, Hong Kong, Singapore and Qatar, women were consistently found to be more socially motivated than men, who were found to be more ambitious and motivated by becoming famous, making lots of money and outperforming others (Korpershoek et al., 2021).

A different motivation was observed in China, where competition between peers was reported to drive women's desire to study. According to Lo et al. (2019), the increasingly complex conditions of modern life in China contribute to an increase in women's motivation. Women strive just as hard as men to continuously develop their abilities and qualities. This claim is consistent with a study by Zhang (2011), with 544 middle and high school students in China, where girls were observed to be as highly competitive as their male counterparts. This motivation reflects the need for self-actualisation.

There are more similarities than differences in the motivations identified in these studies. Women are motivated to pursue education by the need to be relevant and belong. In this quest, they opt for careers that allow them to interact with other people in society and feel the direct impact of their interaction (Cross & Madson, 1997; Burns & Rice, 2018). This might explain their preference for occupations oriented towards working with people (non-STEM fields) rather than working with objects (STEM fields) (Su et al., 2015; Eccles & Wang, 2016; Kuhn & Wolter, 2020).

Although not substantial enough to generalise, it can be argued that females' choices of career paths are linked to their need for belonging and value for self-esteem, which, in turn, are subject to family and sociocultural expectations. According to Meece et al. (2009), individuals begin to identify themselves at an early age with their family and sociocultural values, which influence their beliefs, attitudes and behaviour concerning their choice of career paths. Spelke (2005) also asserts that distinctions in career choices between women and men are not due to differing cognitive abilities but sociocultural factors, such as subtle gender expectations during childhood. These factors influence occupational identities and aspirations. Thus, it follows that social expectations play an important part in identity formation, which, in turn, is crucial to the formation of motivations (Meece et al., 2009). These studies could be interpreted differently, however, in this study, it implies women's that to promote young enrolment into STEM pathways, they need to be assured that they can remain true to their sociocultural cultural norms and values with a career in STEM fields. In summary, from this section, insight has been gained as to what motivates women to choose careers in non-STEM fields, which are family and sociocultural expectations. The next section further examines what well-established theories communicate about the factors that influences female student career enrolment behaviour.

2.6 THEORIES OF ENROLMENT BEHAVIOUR

Several theories exist explaining how students make academic and career choices. Some of these theories include Krumholtz's social learning, Super's developmental self-concept theory, Holland's theory of vocational types, Ann Roe's needs theory, Roe's personality theory, expectancy-value theory, theory of planned behaviours, and social cognitive career theory. While it is acknowledged that these theories provide a good ground for understanding career decision-making, the theory of reasoned action, the theory of planned behaviours, the expectancy-value theory, and the social cognitive career theory were considered relevant to the present study and more robust. They emphasise how individual factors influence career choice while considering the social environment in which individuals perform the behaviour. This emphasis is consistent with the value position of this study regarding the orientation to knowledge, which is that knowledge is individually and socially constructed**.** The selected theories are discussed next.

2.6.1 Theory of Reasoned Action

The theory of reasoned action (TRA) (Constanze, 2021) posits that the decision to perform a given action is predicted by intention and intention, in turn, is determined by the individual's attitude and subjective norms, as shown in Figure 2.2. Attitude refers to the individual's beliefs about "the possible personal consequence of the action" (Sutton, 2001 p.65), while subjective norm refers to how the individual thinks others will see them if they choose to perform the action (Constanze, 2021). To wit, subjective norms reflect the influence of the external environment on an individual's decision-making or actions, while attitude reflects the inherent influence. TRA has been widely used in information system research for understanding people's decision-making processes. Davis, for example, used TRA to develop the well-known technology acceptance model (TAM) (Samar et al., 2020). The implication of TRA in motivating women to enrol in STEM pathways is the identification of three constructs: Intention, Attitude, and Subjective norm, that are significant to women's decision to choose a subject or career. Figure 2.2 shows TRA in a diagram.

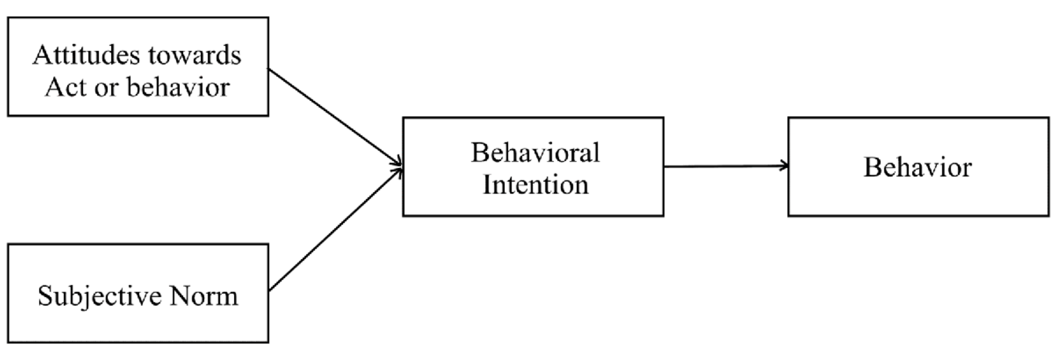

Figure 2. 2: Theory of reasoned action (Constanze, 2021)

2.6.2 Expectancy-Value Theory

The expectancy-value theory (EVT) was initially developed to explain young people's achievement in and selection of mathematics as a subject (Jacquelynne & Wigfield, 2021). Subsequently, it is used to understand subject selection in several other fields. EVT posits that young people choose school subjects based on their expectations for success and the value of the subject's outcome. The theorists define expectancies as an individual's hope that their performance of a task would end up successful, while value is the importance that they attach to succeeding in a task. Expectancies and values are assumed to be determined by someone's competence beliefs, individual goals and affective memories. These aspects are subject to previous experiences, a socialiser's expectations, and other external cultural milieu. As shown in Figure 2.3, the theorist explains the four sets of values young people ascribe to different options, which play an influential role in them making a choice: (i) Attainment value: the importance attached to doing well in the task, (ii) Intrinsic value: enjoyment when performing the task, (iii) Utility value: the belief of the usefulness of a task for achieving either current or future goals and (iv) Cost: the sacrifices they are willing to make to accomplish the task. In summary, the implication of the EVT theory on women's decision to choose and enrol in STEM is that two constructs are relevant to women's decision to enrol in STEM pathways: (i) expectation for success and (ii) task value, as shown in Figure 2.3 below.

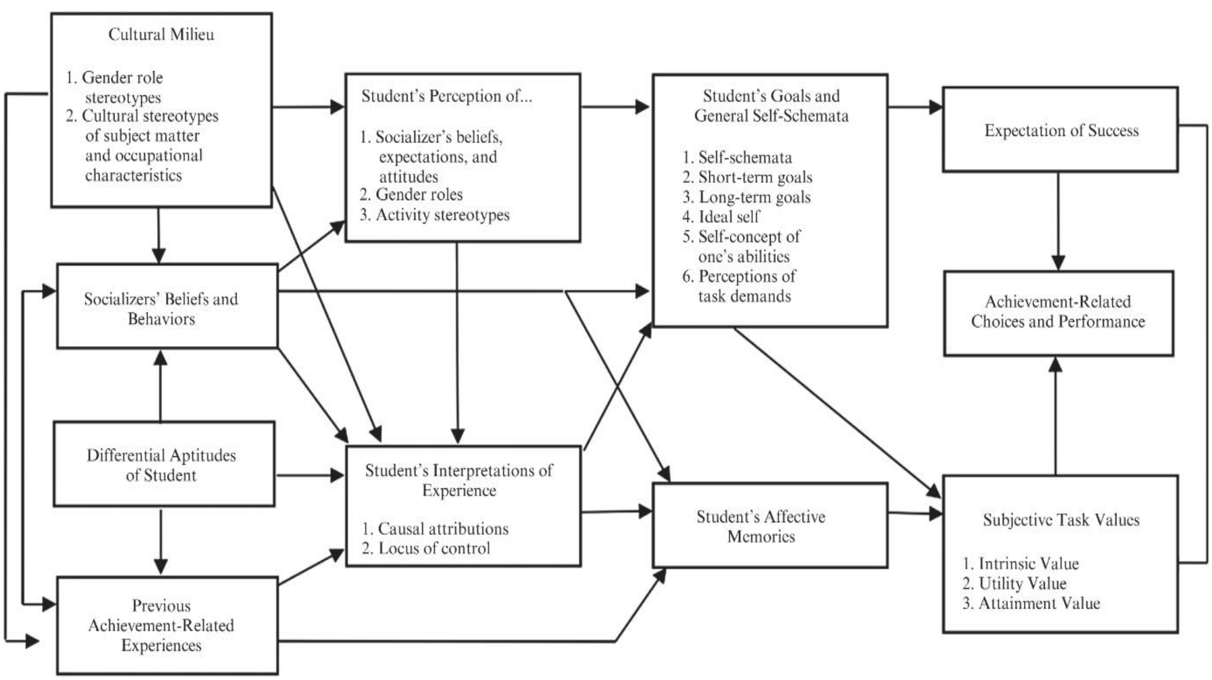

Figure 2. 3: Expectancy-Value Theory **(Jacquelynne & Wigfield, 2021)**

2.6.3 The Social Cognitive Career Theory.

The social cognitive career theory (SCCT) has demonstrated relevance in understanding interests and choices in academic disciplines, promoting academic interests and aspirations, coping with barriers, and supporting students' academic and professional decision-making processes (Byars-Winston et al., 2011; Inda et al., 2013; Mendez et al., 2017; Kantamneni et al., 2018; Duttaa et al., 2019; Lent & Brown, 2019; Chan, 2020).

SCCT was developed by Lenta & Brown (2019) as an improvement to Bandura's Social cognitive theory, which emphasises the link between individual experiences, the actions of others, and environmental factors and academic performance (Abdalhay et al., 2023). Proponents of SCCT explain how students develop academic interests, make choices and achieve success using three models: the interest model, choice model and success model. The fourth and fifth models were later added to explain how students experienced career "satisfaction" and "self-management", respectively (Abdalhay et al., 2023). This study is concerned with the first and second models, which address developing academic interest and making academic choices.

According to the interest and choice model, the decision to choose a career path builds from the people's interest (liking and enjoyment) in the career path, which is formed by certain individual and environmental factors in combination. Figure 2.4 is a diagrammatical representation of the SCCT theory interest model and is explained further in the next subsection.

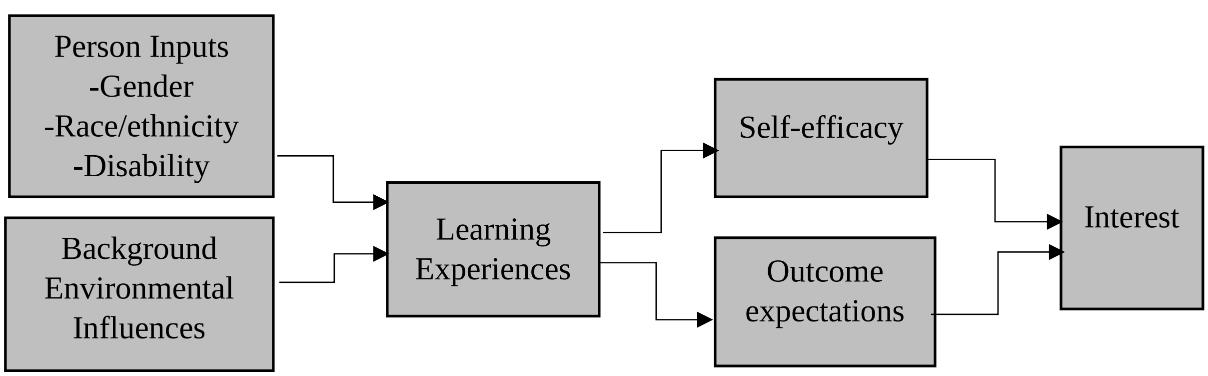

Figure 2. 4: How career interests build. Adapted from (Abdalhay et al., 2023)

2.6.4.1. The Interest Model

According to the interest model, a set of individual and environmental variables collectively shape a student's academic and career interest development. Some of these variables have a direct influence on interest, while others have an indirect influence. The variables with direct influence are individual variables: self-efficacy and outcome expectation. Self-efficacy is an individual's judgement about how well they can perform a specific task. Theories of self-efficacy assert that people are more likely to participate in tasks for which they have high self-efficacy and less likely to participate in those for which they do not (Jordan & Carden, 2017). This likelihood is the same for outcome expectation, which is the belief about the value of the outcome of a task that an individual intends to perform (Abdalhay et al., 2023). Individuals are more likely to engage in activities for which they harbour high outcome expectations and less likely to engage in those for which they do not. This implies of this for this study is that a woman, who is, arguably, driven by the need for interaction, is less likely to opt for a career in mechanical engineering because it is presumed to involve working with machines, not humans.

The model further explains that these individual variables are formed through exposure to different learning experiences and that learning experiences are subject to environmental and other individual factors. Thus, as a child develops into adulthood, the sociocultural processes they pass through, such as gender socialisation, social stratification, responsibilities and other random life events, combined with learning experiences from teachers, peers and parents, continue to shape their competence beliefs and outcome values for a task. Hence, children's competence beliefs and outcome values of a task will shape their interest in the task. Next, the study describes the choice model, which explains how an individual chooses an academic discipline or career. Figure 2.5 is a diagrammatical representation of the choice model.

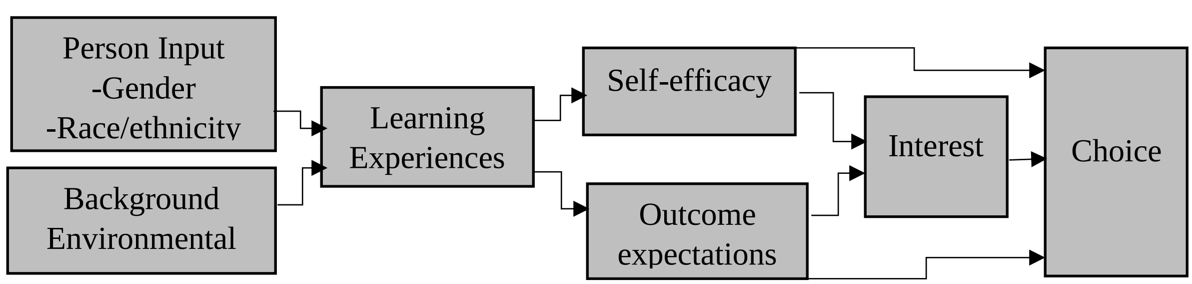

Figure 2. 5: How academic and career choices are built. Adapted from (Abdalhay et al., 2023)

2.6.4.2. The Choice Model

The choice model is a continuation of the interest model. It explains that after the interest in a career path has been built, the decision to take the career path emerges. The theory also demonstrates that self-efficacy and outcome expectation can affect choice directly, irrespective of interest. The direct influence of self-efficacy and outcome expectation on choice is considered more potent than their indirect influence through interest. The authors argue that the potency of interest can only be experienced if there is an enabling environment to support it. Sometimes, a student might have an interest in pursuing a specific degree but is unable to do so because of some environmental factors, such as an unsupportive parent or a demotivating learning environment.

The theories reviewed provide an understanding of the constructs that may predict women's choice-making or enrolment behaviour. These constructs: attitude, intention, task value, outcome expectation and self-efficacy according to the theories reviewed are suggested to predict actions or behaviours. These variables are a function of external environmental variables. This claim is consistent with the argument advanced in Section 2.3 that the educational choices of female students are subject to environmental factors, such as family and socio-cultural expectations. These theories, together with Maslow's needs hierarchy theory, form a strong theoretical base for the study's argument that individual and environmental factors work in tandem to influence female students' enrolment in STEM disciplines. The next section looks at empirical literature that investigated the factors that influence enrolment into STEM to see what has been specifically identified.

2.7 EMPIRICAL LITERATURE ON FACTORS INFLUENCING ENROLMENT IN STEM DISCIPLINES

The study conducted a critical review of the most cited factors that predispose female students to enrol in STEM disciplines. The keyword search phrases were: "subject choice", "career choice", "STEM engagement", "STEM enrolment", "female", and "influencing factors". Harzing.com published software, and academic databases such as *IEEE Xplore*, *Google*, *Scopus*, *Google Scholar*, *Crossref*, *Microsoft Academic*, *ScienceDirect*, and *ACM Digital Library* were used to search for literature. The period of publication ranged from 2000 to 2022. The review includes both studies targeted at the Nigerian audience and those targeted at the non-Nigerian audience.

2.7.1 Studies Conducted Outside the Nigerian Audience

This section looks at studies conducted targeted at Western and Asian audiences. The factors identified revolve mainly around individual and environmentally related factors.

2.7.1.1 Individual Factors Influencing Female Students' Enrolment in STEM Disciplines

Self-efficacy has been empirically investigated and shown to affect female students' enrolment in STEM disciplines significantly (Jordan & Carden, 2017; Rahman et al., 2018; Otoo et al., 2018; Gana et al., 2019; Sovansophal & Shimizun, 2019; Thompson et al., 2024). According to existing literature, it is one of the most significant individual-related factors that affects the enrolment in STEM disciplines of female students (Sovansophal & Shimizun, 2019; Rahman et al., 2018; Kuzhabekova & Almukhambetova, 2020 ; Thompson et al., 2024). and is reported to be influenced by personal experience factors, such as teacher motivation, parent encouragement, successful grades, and role models (Tandrayen-Ragoobur & Gokulsing, 2021).

Several studies also claim that a feeling of belonging is closely related to female students' intention to enrol and persist in a discipline (Robnett, 2016; Tellhed et al., 2017; Diekman et al., 2019; Hoffman et al., 2021). STEM belonging has been defined as "the extent of the psychological connection a student has to other individuals in STEM or the extent to which a student feels personally accepted, respected, included, and supported by others in the STEM social environment" (Ma, 2003, p.340). According to Jones et al. (2014), Godwin et al. (2016) and Cheryan et al. (2017), STEM fields are perceived to be male dominated, which influences women's motivation to take up STEM paths. For example, Makarova et al. (2019), conducted an empirical study to investigate Swedish secondary school students perceived masculine image of STEM subjects and how it affected their enrolment in a STEM major at university. The study utilised a quantitative approach to collect and analyse data from 1,364 male and female students on their perceived gendered image of chemistry, physics and mathematics and its relationship with their enrolment in a STEM major.

Their results revealed that mathematics is viewed as masculine, followed by physics and chemistry. However, the results reported by the female respondents only showed that all three subjects were viewed equally masculine. Further analysis revealed that women who preferred non-STEM careers had a higher gendered image of the subjects than those who preferred STEM careers. This provides strong empirical evidence for the contention that young women might be discouraged from enrolling in STEM disciplines because of a lack of identification with them. Further, in a cross-sectional study of 1, 479 students in Colorado, USA, Banchefsky et al. (2019) revealed that female students perceived STEM fields to be for a certain class of individuals to which they did not belong. The authors argue that female students lack a sense of belonging in STEM classes. Hence, they are unable to build positive, significant and lasting interpersonal relationships with their peers. A lack of a sense of social belonging can significantly impact women's persistence in male-dominated fields because they would feel isolated, even if this is not the case (Furrer & Skinner, 2003; Rosser, 2009; Buse & Pierce, 2010; Archer et al., 2013; Hamrita et al., 2023).

Aside from social belonging, ability belonging—having a feeling of being competent to be part of a group—has been shown to affect females' enrolment in STEM (Ito & McPherson, 2018; Banchefsky et al., 2019). The authors argue that female students' perceptions of STEM as requiring innate intelligence, as well as their perception that hard work does not guarantee success in STEM fields, are among the barriers to their participation in STEM (Archer et al., 2020). Given all the aforementioned, it could be assumed that female students have a somewhat distorted image of STEM fields. The notion that STEM fields are masculine and the feeling that they are meant for inherently intelligent individuals are all barriers to their enrolment in STEM.

2.7.1.2 School Factors Influencing Female Students' Enrolment in STEM Disciplines

Researchers have also investigated the effect of school-related factors on female students' STEM enrolment. Sovansophal and Shimizun (2019) conducted a study among 1,281 Cambodian students and revealed that tutors unintentionally dissuaded female students in class by underrating their abilities while overemphasising the abilities of male students. Other studies have also shown this to affect female students' enrolment and persistence in STEM disciplines (Lavy & Sand, 2015; Terrier, 2016; Pov, 2023). The role of teachers in a student's learning process cannot be overemphasised; thus, teachers' behaviour, such as engaging more and differently with some students than with others, can result in uneven learning motivation and outcomes among students (Griffith, 2010; Bertrand & Duflo, 2017; Carlana, 2019; Papageorge et al., 2020).

Their finding supports other scientists' claims that the depiction of STEM subjects as a male domain also demotivates females from taking STEM pathways (Kelly, 2016; Samuelsson &

Samuelsson, 2016; Machocho Mwang'ombe & Mweru, 2023) The authors explain that textbooks show scientists as men and teachers giving examples in engineering and technology classes with concepts that align with male students' interests. All these factors, according to the authors, are forms of attention bias that favour males and negatively impact female students' interest in STEM. Another significant school-related factor that persuaded girls to enrol in STEM courses was having a female STEM instructor. Studies such as that of Carrell et al. (2009), Stearns et al. (2016), Cheryan et al. (2017) and Buenestado-Fernández et al., (2024), report that females are more likely to choose a STEM career when taught by female teachers.

2.7.1.3 Familial Factors Influencing Female Students' Enrolment in STEM Disciplines

Several authors, including Tan et al. (2013), Bowden et al. (2017), Sheldrake (2018), Guo et al. (2019), Kuzhabekova and Almukhambetova (2020), and Plasman et al. (2020), report that female students who showed interest in STEM career paths had a family member(s) working in a STEM field, and the students indicated that their choice was based on this influence. The authors argue that such parents or family members might communicate the positive aspects and prospects of their career paths to their children. Kniveton (2004), claims that parents tend to show heightened support for learning activities that mirror their careers. Parental influence may be intentional when parents choose their children's career paths or unintentional when children in their very early years identify with their parents' occupations (Sheldrake, 2018).

The influence of parental education level has also been reported to influence female students' STEM career choices (Sonnert, 2009; Spera et al., 2009; Eccles & Wang, 2016; Burusic et al., 2018; Luo et al., 2022). The experiences of highly educated parents predispose them to value STEM careers more (Almarode et al., 2018), leading to them supporting and encouraging their children's STEM engagement (Dabney et al., 2016), and, in turn, the parental support and encouragement fosters students' STEM interests, activities and achievement, all of which are predictors of children's STEM career aspirations and choice (George-Jackson, 2014; Sahin et al., 2017). Furthermore, the exposure education affords parents makes them more inclined to set higher expectations for their children's STEM engagement and achievement (Simpkins et al., 2006). Parental expectancies have been seen to exert an influence on students choosing advanced STEM subjects in school (Harackiewicz et al., 2012; Rozek et al., 2015), an indication of such children choosing a STEM career path in the future (Card & Payne, 2021b).

2.7.1.4 Cultural Factors Influencing Female Students' Enrolment in STEM Disciplines

Mujtaba and Reiss (2015) and Kuzhabekova and Almukhambetova (2020), find that cultural gender role expectations influence female learner STEM enrolment. The authors highlight that Kazakhstani families are expected to have at least one son to continue the family bloodline; consequently, preference is given to male children's education. They are encouraged to choose pathways that might lead to high-paying jobs, and their parents are willing to pay for such pathways, which usually have higher tuition fees. Conversely, young female learners can only take such expensive pathways if they find scholarships because they are expected to become housewives and mothers, and thus, it is not worth spending much on their education.

Such cultural norms and expectations have also been shown to influence female STEM enrolment in a study by Chan (2022). Women are expected to be family-centred (Yoshikawa et al., 2018), and, thus, should only take jobs that allow them time to care for their homes (Charlesworth & Banaji, 2019). Such expectation steers them from careers like STEM (Ceci & Williams, 2012). The influence of culture also emerged in cross-cultural research. Students from collective cultures had higher gender disparity in STEM enrolment than those who did not conform to social norms and were from individualist cultures (Mau et al., 2020). Students from collective cultures conform to social norms. Their social behaviour is guided by the customs, values and beliefs of their culture rather than their desires or interests. Being unique or refusing to comply with norms might result in disapproval and rejection by society and bring disgrace to one's family (Chan & Huang, 2022). Spearman and Watt (2013) and McDaniel (2016), also reveal that women in more gendered-equal societies have more positive attitudes towards STEM and higher STEM self-efficacy, and the gender disparity in such societies is lower.

Together, these studies provide important insights into the factors affecting female students' enrolment in STEM. The literature suggests that female students' STEM self-efficacy, social belonging, parental education, parental occupation, STEM teachers' behaviour, cultural norms and expectations are the most significant factors influencing enrolment in STEM. However, these results might not concur with the Nigerian audience because the difference in sociocultural values might shape how people view and interact with their world in general. This argument is supported by results from a study by Bahar and Adiguzel (2016), which compared the factors affecting

American and Turkish students’ enrolment in STEM. Their results revealed a difference in factors: while American students were most affected by self-motivation, Turkish students were most affected by their parents’ income and occupation. Hence, research conducted among the Nigerian audience is reviewed next.

2.7.2 Studies Conducted Among a Nigerian Audience

The literature search revealed that in Nigeria, STEM education research is scarce. This outcome is not surprising as results from several meta-analyses on STEM education research reveal that the number of African-centred research is low compared to Western- and Asian-centred research. For example, a meta-analysis of 798 STEM-related research studies between 2000 and 2018 showed that 75% of the authors are from the USA, followed by Australia, Canada, Taiwan and the UK. No African country was represented among the top 10 countries (Li et al., 2020). Thus, the few pieces of literature most relevant to this study were identified and are presented here.

2.7.2.1 Individual Factors Influencing Female Nigerian Students’ Enrolment in STEM Disciplines

Ugwuanyi and Okeke (2020), conducted a study among 225 undergraduate students in Enugu, Nigeria, to investigate factors that influence their enrolment in STEM disciplines empirically. Their work identified motivation, self-efficacy, and self-esteem as the most significant determinants of female students’ STEM enrolment. In a similar study with 400 senior secondary school students in Anambra, Nigeria, self-esteem and self-efficacy significantly affected students’ engagement with mathematics (Ugwuanyi & Okekeet al., 2020). The female students reported they did not believe they were equal to the task of succeeding in STEM fields despite their good grades in STEM subjects. The authors attribute such low self-perception to a lack of motivation emanating from the environment. Akinsowon and Osisanwo (2014), argue that self-efficacy is influenced by encouragement and discouragement from people in our lives, people will only encourage us towards values to which they attach importance. If the individuals around the girls do not associate value with enrolling in STEM disciplines, they are not likely to persuade the girls that they possess the capabilities to succeed in fields.

Other individual-related factors that have shown a significant impact on STEM enrolment are the lack of interest, lack of career-driven goals and an absence of role models (Akinsowon &

Osisanwo, 2014; Osagie & Alutu, 2016; Okwelle & Alalibo, 2017; Eze & Adamu, 2020). For example, the work by Osagie and Alutu (2016), with 150 senior secondary school students in Edo, Nigeria, showed that 88.7% of female students expressed a lack of interest in STEM. They indicated that STEM subjects were boring, and they preferred careers in the arts and humanities, where they could interact with people more than in STEM careers, which were more related to inanimate objects.

Studies conducted by Maryann and Agommuoh (2017) and Dada (2017) also revealed that females opted out of enrolling in STEM disciplines because they did not see females in STEM fields, so they are not inspired to enrol. Eraikhuemen and Oteze (2015) studied 438 students from two universities in Nigeria and found that the low number of female STEM professionals for young women to look up to have the most significant effect on their STEM predisposition. Role models arouse, direct and sustain an individual's motivation towards an identified or yet-to-be-identified goal. Therefore, exposing young female students to female STEM professionals might positively impact their interest in STEM disciplines. There is similarity in the factors identified in the literature among the non-Nigeria and Nigeria context. Specifically self-efficacy and not feeling belonged or having a role model were identified by the non-Nigeria and Nigeria literature. This implies that these two factors should be considered particularly significant going forward.

2.7.2.2 School Factors Influencing Nigeria Female Students' Enrolment in STEM Disciplines

School-related factors were also reported to influence female enrolment in STEM disciplines, although some of the factors had a lesser impact. For example, Maryann and Agommuoh (2017) investigated if the behaviour of STEM teachers discourages young women from enrolling in STEM disciplines when they entered polytechnic. Their study revealed that teachers' behaviour, whether intentionally or unintentionally, dissuaded female students' enrolment in STEM. Further, Ogunjuyigbe et al. (2006) found that 62.2% of the girls disagreed that teachers gave more attention and encouragement to male students in science and technology classes. However, an empirical study involving 438 students from two universities in Nigeria by Eraikhuemen and Oteze (2015) revealed that the low number of female STEM professionals to whom young women can look up has the most significant effect on female students' STEM predisposition, which was also supported by Maryann and Agommuohy (2017) and Akinsowon and Osisanwo (2014).

In a more recent study, Olajide et al. (2019) assert that weak government policies are the main reason why women are underrepresented in STEM. They state that there is near or total neglect of women's conceivable contribution to the nation's development and mention the Federal Republic of Nigeria Nation Policy on Education (2013) and the Federal Republic of Nigeria National Science, Technology, and Innovation Policy (2012), which both only passively refer to women in education generally, and in the acquisition of STEM skills. The authors highlight the need for policies that recognise female youths as a significant group in the nation's growth.

Further, Akinsowon and Osisanwo (2014), proclaimed the significant effect of curriculum development on female students' STEM enrolment. They used computer science as an example, in which programming is portrayed as the only application area in computer science. This overemphasis on programming overshadows other application areas. Accordingly, female and even male prospective students have the impression that computer science is all about programming, which, according to the authors, steers many female students away from computer science. Their claim is validated by the argument from the literature about the absence of a link between STEM subjects and female students' interests (Khan & Luxton-Reilly, 2016; Marosi et al., 2021). According to Marosi et al. (2021), teachers fail to connect STEM subjects to ideas and topics that interest female students. Appealing to female students' interests and values when structuring the content of STEM subjects might encourage more girls to think differently about STEM. Kelley and Knowles (2016), recommend that outcomes for learning a STEM subject should purposely be integrated into other subjects, such as mathematics or technology subject outcomes in an art class or vice versa. For example, with girls interested in fashion, teachers could promote fashion technology and explain how they could apply electronics to their clothing, backpacks or notebooks in a bid to make engineering courses attractive to girls (Khan & Luxton-Reilly, 2016).

There is also a claim that female students often struggle to link what they learn in class to the real world around them. According to Milner-Bolotin, (2018), this is because too much focus is on instilling knowledge in STEM classes, and very little importance is placed on the application of such knowledge. A poor curriculum that focusses on memorization rather than understanding, application and analyses can discourage learners' interest in STEM education (Ndiku & Kaluyu, 2020). For instance, as students learn quadratic equations, very few know that these equations are crucial to constructing buildings or calculating profits; hence, students often ask troubling questions like “When is this ever going to help me?”. In a study by Cox et al., (2018), students reported that the lack of connection of STEM concepts to the real world made it difficult for them to understand and remember the concepts. Ndiku & Kaluyu, (2020) also found that teacher centred teaching pedagogy. In other words, the absence of dynamic curriculum materials and tutors' pedagogical ability to emphasize inclusivity and integrate real-world application of STEM education concepts into lessons in secondary school can discourage learners from building an interest in STEM disciplines. Again, there is similarity in the factors identified in the literature among the non-Nigeria and Nigeria context. The tutors' behaviour was identified in both non-Nigeria and Nigeria context. This implies that this factor should further investigated going forward.

2.7.2.3 Familial Factors Influencing Female Nigerian Students' Enrolment in STEM Disciplines

Surprisingly, there is a paucity of literature on the influence of parentally related factors on female Nigerian students' STEM enrolment. Most existing research focused on general career interests, not STEM career interests in particular. The results from the very few that focused on STEM careers revealed that parentally related factors were among the least-rated factors affecting students' enrolment in STEM disciplines (Okwelle & Alalibo, 2017; Eze & Adamu, 2020). Of the parental factors, parental occupation was shown to have the most effect (Lawan & Muhammed, 2014). Again, this might be a deliberate influence, whereby parents choose their children's career paths, or it could be unintentional, whereby children in their very early years identify with their parents' occupations (Sheldrake, 2018). Yet again, parental occupation appeared in the non-Nigeria and Nigeria literature reviewed in this study. This implies that this factor must be further investigated.

2.7.2.4 Cultural Factors Influencing Female Nigerian Students' Enrolment in STEM Disciplines

Studies such as those by Aderemi et al. (2013) and Osagie and Alutu (2016) claim that the ideologies and identities constructed by sociocultural norms and expectations influence women's enrolment in STEM.

The literature review disclosed that most studies identified individual-related, school-related and family-related factors. However, individual factors, such as low self-efficacy, low self-esteem, lack of interest, lack of motivation, lack of career goals, low ability belonging and low social belonging, were the most useful predictors of female students' enrolment in STEM. As stated in Dada (2017), since female students do not show a lack of intellectual capacity to embark on STEM careers in future, all the reasons might be highly influenced by the environment. This argument is consistent with Spelke (2005), who asserts that women's choices of career disciplines are not due to a lack of intellectual abilities but to environmental factors. This suggests that if female students are given an adequate motivational 'push', they may begin developing a positive self-perception toward STEM.

Based on Maslow's hierarchy of needs, the theories on enrolment behaviour and the findings from empirical studies, the study argues that individual, family, school and cultural factors play a significant part in female students' attitudes towards STEM disciplines, which, in turn, influence their decision to enrol in STEM. With insight from these, a conceptual framework is presented in Chapter 3, explaining how these concepts individually contribute to solving the research problem.

2.8 MOTIVATING WOMEN TO ENROL IN STEM DISCIPLINES

This section looks at studies aimed at increasing female students' engagement and enrolment in STEM disciplines to identify knowledge deficits. The literature review revealed that interventions primarily involved the development of innovative STEM teaching approaches (Christensen & Knezek, 2016; Brown & Brown, 2019; Mostoli et al., 2019), and STEM educational technologies (Wijekumar et al., 2014; Karam et al., 2017; Agu & Samuel, 2018). The interventions were organised in the context of after-school activities (Drobnis, 2010; Schilling & Pinnell, 2019; Todd & Zvoch, 2019), and regular classroom activities (Cantley et al., 2017; Werner, 2017), and were mostly for a short duration (one to 24 hours) (Feng & Tuan, 2005; Matson et al., 2007; Marshall et al., 2010), and mid-termed duration (one to nine weeks) (Summers & Bauman., 2010).

Surprisingly, the studies did not investigate the reasons for women's low participation in STEM discipline; they relied on theories (Christensen & Knezek, 2016; Brown & Brown, 2019; Mostoli et al., 2019), or existing literature that investigated the factors (Heddy, 2014). Furthermore, the individual student-level factor attracted the most interest (Prieto-Rodriguez et al., 2020). For instance, relying on the constructivist theory, Feng and Tuan (2005), argued that a lack of motivation was the single most important reason why students opted out of taking chemistry courses. They designed an intervention for motivating and improving learning about acids and bases in chemistry among 11thgrade female students. They used the attention, relevance, confidence and satisfaction (ARCS) model to investigate the effectiveness of their teaching approach. In their study, the ARCS model was used to design a 10-hour acids and bases lesson for the students. On post-assessment of their achievements in acids and bases lessons, the students showed a significant achievement. Despite the constructivist theory being a well-established theory, the study should have investigated whether the constructivist theory is true to their audience.

Chittum et al. (2017), developed the MUSIC model and used it to design an after-school program to foster students' participation in STEM classes. The MUSIC model is an acronym for empowerment, usefulness, success, interest and care. The authors based the component of this model on the expectancy-value theory (EVT), which postulates that choice of action is determined by expectations of success and value for the desired outcome. Their study participants were students in the fifth, sixth and seventh grades. Their program was conducted for six weeks, whereby the students participated in specially designed 90-minute after-school programmes once a week for six weeks.

Some studies (Christensen & Knezek, 2016; Brown & Brown, 2019; Mostoli et al., 2019), relied on more than one theory. For instance, as part of a project funded by the European Union's Horizon 2020, researchers from the Finnish Institute for Educational Research at the University of Jyväskylä, Finland, Mäkelä et al. (2020), developed a framework relying on Vygotsky's socio-constructivist learning theory and Dewey's educational theory. Their intervention was targeted at primary, lower secondary and upper secondary school students. Their framework consists of six categories of design principles: (1) general principles, (2) cross-curricular skills, (3) ways of teaching and learning, (4) socio-emotional aspects, (5) educational compatibility, and (6) gender inclusion. The problem with relying solely on existing literature or theories is that the factors may not apply to a specific audience because of the difference in sociocultural environments, as argued by Bahar and Adiguzel (2016). This study argues that it is imperative to consider the broader social context of this issue by investigating the sociocultural context surrounding an audience.

Furthermore, the studies were mostly quantitative (Kolne & Lindsay, 2020; Prieto-Rodriguez et al., 2020), using self-reported surveys, achievement tests and grade assessments to evaluate the success of their interventions. The problem with quantitatively assessing such short-term programs is that they capture short-term outcomes that are not indicators of long-term engagement, such as enrolment in STEM disciplines (Prieto-Rodriguez et al., 2020). Students need to be continuously engaged over a long period so that they develop relationships with peers, mentors, and the STEM community and build permanent and meaningful relationships with STEM (Prieto-Rodriguez et al., 2020). In addition, using quantitative approaches to measure the effectiveness of interventions means that phenomena such as perceptions, feelings or self-efficacy in STEM cannot be explicitly measured. A qualitative approach allowing for a deep understanding of phenomena that cannot be explicitly measured would be a better fit. For instance, elevating the proliferation of low self-efficacy as being the single most important factor affecting women's enrolment in STEM, Summers and Bauman. (2010), investigated the effect of a counselling intervention on sixth-grade students' self-efficacy in mathematics. The intervention lasted nine weeks, with one hour of counselling in the classroom each day. They used the attitudes toward mathematics (ATM) quantitative scale consisting of 40 items to evaluate the effectiveness of the intervention. Even though the authors reported that the intervention had a positive impact on female students' confidence in mathematics, they were silent about the effect of the intervention on their long-term engagement leading to enrolment in STEM disciplines in future.

Since these interventions intend to increase women's enrolment in STEM disciplines, there is need to investigate what exactly the problem is (among their specific audience) and be explicit about what the indicator(s) for enrolment into STEM disciplines are so that they make an informed decision on how best to evaluate the interventions. Comparing pre-test scores to post-test scores, assessing grades or quantitatively assessing self-efficacy are not realistic ways of assessing whether or not a student will eventually enrol in a STEM discipline.

Based on the earlier review conducted in this chapter on enrolment theories and empirical studies, this study argues that rather than only assuming that female students possess some personal qualities which require correction for them to be able to enrol in STEM disciplines, interventions also need to identify and help them challenge the discriminatory practices and values in their environment that assumes their unfitness for STEM.

Another issue identified from the review is that the interventions focused on students' engaging in a specific STEM subject's concept. For instance, Ezeudu (2013) designed and investigated the effect of concept maps in helping students build an interest in organic chemistry classes. A concept map is a diagrammatic representation of a concept that outlines the relationship between the variables of a concept. Four hundred and thirty-five learners were randomly chosen from 30 secondary schools. Two hundred and twenty students formed one group, and 215 students formed another. Students in both groups were taught the same topics in organic chemistry for four weeks. One group was taught using concept maps, while the other group was taught using conventional classroom teaching. After the four-week experimental period, the achievement and retention test in organic chemistry (ARTOC) was used to evaluate the effectiveness of concept maps. Extensive research conducted over the past decade has also proposed the effectiveness of some existing pedagogical approaches on female students' engagement and enrolment in STEM disciplines.

2.8.1 Efficacy of Established Teaching Pedagogies on Female Enrolment in STEM Disciplines.

Several studies investigated the effectiveness of teaching pedagogies that they did not create but were well-known in the educational domain. For instance, to solve the problem of the absence of a link between STEM subjects and female students' interests, the inquiry-based learning approach and culturally relevant learning approach were investigated and recommended. According to Ottenbreit-Leftwich et al. (2021), the educational motivation of boys and girls might differentiate their values for different methods of instruction. This claim has been supported by other studies (Seron & Silbey, 2004; Zastavker et al., 2006; Khan & Luxton-Reilly, 2016; Udu, 2018; Benabentos et al., 2021; Marosi et al., 2021; Mystakidis 2021).

Inquiry-based learning (IBL) is a student-centred approach motivated by questions and natural curiosity. Rather than telling female students what they need to know, teachers should encourage them to ask questions, investigate phenomena, apply principles and share ideas (Gholam, 2019). According to Attard et al. (2021), IBL is an approach that encourages students to learn through investigation and discovery. In this way, they notice patterns and discover underlying causalities. The teacher's role is to spark curiosity and prompt reflection. The advantage of this approach is that female students can ask questions about what interests them, which makes learning more relevant and meaningful to them.

Furthermore, research indicates that when students are allowed to pose questions based on their relevance to them, it deepens their understanding of content and builds their initiative (Sockalingam et al., 2011; Gu et al., 2015; Abdurrahman et al., 2019; Attard et al., 2021). Gholam (2019) states that when students build understanding through thinking and posing questions, they derive satisfaction, which ignites their curiosity about things around them. When this approach is applied to teaching STEM subjects to female students, it will create a connection between their interests and STEM subjects.

Culturally relevant education is a pedagogy that recognises the value of incorporating students' cultural backgrounds, interests and lived experiences into all aspects of STEM teaching and learning in the classroom and throughout the school. According to Agwu (2009, p.172), “incorporating means that what the curriculum offers must be related to what the community requires”. Brown et al. (2019) recommend the use of culturally relevant pedagogy to promote STEM enrolment among female students, arguing that when STEM learning is centred around the lived experiences of students, they are “more personally meaningful, have higher interest appeal, and are learned more easily and thoroughly” (Gay, 2010, p. 106). Unfortunately, according to Brown et al. (2019), the importance of cultural relevancy in STEM teaching and learning is among the least studied areas of research. With culturally relevant pedagogies, female students harbouring family and societal expectations and values can be accommodated, and they can extend their information and experiences and connect them with their STEM subjects. The second problem is discussed next.

In addition, to resolve the absence of a connection between STEM concepts and the real world, instructional approaches, such as the project-based learning and problem-based earning approaches, were tested and proven effective pedagogical approaches. Project-based learning (PjBL) is a student-centred approach that allows students to solve real-world problems by taking part in contextually rich projects (Qisthi & Arifani, 2020). Research indicates that PjBL better enhances student engagement, interest, and mastery of concepts (Kazun & Petukhova, 2018; Kuswandi et al., 2018), as opposed to the direct presentation of facts approach. This is because, in PjBL, students are hands-on, which makes them practically involved with concrete materials. According to Kuswandi et al. (2018), PjBL closely reflects the scientific method of problem-solving, whereby students are challenged to plan, measure, evaluate, predict and interpret concepts, which makes learning more engaging. Kazun and Petukhova (2018) also assert that PjBL mimics authentic work practices, so students' interest and curiosity are ignited during learning.

Researchers such as Benabentos et al. (2021) further claim that the main strength of PjBL is that it bridges the gap between theoretical concepts learnt in the classroom and their connections and applicability to the real world, making the learning more meaningful. This claim was also supported by Rugh et al. (2021), who posit that PjBL helps in better retention of concepts and allows students to be in control of the learning process. According to Helle et al. (2006), being in control allows students to decide the pace, sequence and actual learning content. Mystakidis (2021), adds that learner control allows students to solve problems their way, which means that female students can apply the concepts and facts in ways that are personally meaningful to them, which is crucial to subsequent information retrieval.

Recent work on the effect of PjBL on female students' STEM learning concluded that students showed enhanced interest in STEM subjects. For example, research on the effect of PjBL on female students' interest in their engineering program revealed that they displayed enhanced "engagement, enjoyment, motivation, satisfaction, and understanding of real-world phenomena" (Zastavker et al., 2006, p.22). Seron and Silbey (2004), also found that through group work in project-based science and engineering courses, women "developed a culture of shared learning and interdependence". Based on the available literature reviewed, it can be argued that PjbBL can be employed to solve the absence of a connection between STEM concepts and the real world.

Problem-based Learning (PBL) is a pedagogy that enables learners to collaborate by investigating and responding to authentic and engaging open-ended questions (Tan, 2021). According to (Qamariyah et al., 2021, p.123), PBL's open-ended questions mean that "firstly, there is no one clear answer to the problem. Students brainstorm various possible scenarios to arrive at the best solution. This way students are encouraged to analyse and evaluate problems before proffering a reasoned solution. Secondly, they require higher-order thinking skills, as students need to analyse, infer, reflect, and evaluate. Thirdly, the questions call for support and reasoning, hence the teachers' role is to guide students towards searching and arriving at a reasoned solution. Fourthly, they often lead to debate, discussions, and the emergence of new questions which allows students to use relevant prior knowledge to solve new problems".

Studies across different STEM subject areas have shown that PBL can increase female students' interest in different STEM subject areas (Wirkala & Kuhn, 2011). For example, Ottenbreit-Leftwich et al., (2021) studied the effect of PBL on female students' interest and understanding of computer science concepts and found that PBL facilitated the students in using their knowledge in ways that are meaningful to them. PBL has also been hailed as a solution to ensure that students develop a deep understanding and retention of concepts (Wilson, 2021), which has been identified as one of the problems women face in STEM learning. Several works of literature also claim that through PBL, female students develop other desirable abilities of STEM education like cooperation, literature retrieval, decision-making skills and the ability to defend their decisions (Ravitz, 2009; Jan, 2012; Brush & Saye, 2017).

2.8.2 Educational Technologies Designed to Motivate Female Students to Enrol in STEM Disciplines

As regards educational technology, the available tools are mainly computer-assisted learning tools consisting of software packages designed to develop STEM skills, like improving mathematics computation (Cabalo & Jaciw, 2007; Dynarski et al., 2007; Barrow et al., 2009; Cavalluzzo et al., 2012; Beal et al., 2013; Wijekumar et al., 2014; Karam et al., 2017; Agu & Samuel, 2018). Based on the literature review, there is evidence that authors of such interventions believe that girls possess some underdeveloped cognitive abilities which require correction for them to be able to enrol in STEM disciplines. For example, Audu and Ojekudo (2016), argue that the cognitive skills of students need to be stimulated for them to be able to understand and take engineering courses. Accordingly, they designed simulation software for demonstrating oil and gas instrumentation and control flow processes to the students. These authors also built a small-scale power plant and integrated it with a computer simulation to trigger the development of students' cognitive stills. Sevari and Falahi (2018), designed and evaluated the effectiveness of educational software in aiding students to learn mathematics, focusing on the cognitive aspects of their learning. Mellor (2018) also designed an educational game to help high school students better understand the concept of green chemistry while also focusing on the cognitive aspect of learning. Even though the authors reported the software improving students' cognitive ability, authors such as Escueta and Quan (2017) have questioned their impact in the longer term.

The contributions of these studies are appreciated; however, there is room for more research. There is a need for education technologies that draw on the theory and practice of attitude and behavioural change to help young women build positive attitudes to challenge practices to facilitate their enrolment in STEM. To wit, technological interventions need to focus on the affective aspect of students learning. No research focusing on an attitude change approach to increase young women's enrolment in STEM disciplines in Nigeria has been conducted. Hence, this study proposes a persuasive educational technology approach to motivate female students in Nigeria to pursue STEM pathways. The next chapter discusses persuasive technologies (PTs).

2.9 SUMMARY

This chapter presented a review of the relevant literature conducted to understand why female students choose non-STEM professions over STEM professions. The chapter utilised the hierarchy of needs theory, developed by Abraham Maslow, to investigate the primary reasons why young women chose to enrol in school. This was done to gain a broad perspective on the reasons why they choose non-STEM paths over STEM paths. From the literature review, the study argued that family and sociocultural expectations play an important role in identity formation, and the identity formation process, in turn, plays a crucial role in the choice of career paths.

Moreover, enrolment behaviour theories and empirical studies on factors influencing female enrolment in STEM disciplines were reviewed to gain a better understanding of the reasons for women's professional choices. In the chapter, the study argued that individual, family, school and cultural influences combined all have a significant impact on female students' attitudes towards STEM disciplines and, as a result, their decision to enrol in STEM disciplines. The chapter then reviewed the literature on motivating female students to pursue STEM professions. The literature reviewed included studies that have developed innovative instructional approaches, those that tested existing instructional approaches and those that had designed software applications. As such, it emerged that within the existing literature, there was room for more research. Regarding innovative instructional approaches, the study found that researchers mainly focused on correcting the individual-level characteristics of female students. In response, the study argued that rather than simply assuming that female students have some personal qualities that need correction for them to enrol in STEM disciplines, instructional pedagogy designers should also consider the external factors that influence students' participation in STEM disciplines. As regards educational technological interventions, the chapter demonstrated that designers assume female students possess undeveloped cognitive capabilities that need to be corrected. Instead, technologies should be based on the theory and practice of attitude and behavioural change processes to help female students build the affective aspect of learning to facilitate their enrolment in STEM The next chapter reviews the literature on PTs.

CHAPTER 3: LITERATURE REVIEW ON PERSUASIVE TECHNOLOGIES

3.1 INTRODUCTION

The previous chapter was a literature review on STEM education. It looked at the possible factors that could affect female students' enrolment in STEM disciplines. The deduction was that environmental and individual factors work in tandem to influence female students' attitudes toward STEM disciplines, which, in turn, influence their decision to enrol in STEM disciplines. However, the researcher realised that prior studies aimed at motivating female students to enrol in STEM disciplines primarily focused on the individual characteristics of female students. In addition, prior studies assumed that women possessed undeveloped cognitive capabilities that needed to be corrected for them to enrol in STEM disciplines, ignoring the affective aspect of learning, which deals with the students' attitudes. In response, it was argued that interventions should consider the attitudinal change process, also known as the persuasion process, as it deals with the affective aspect of students' learning, which, if robust, could help female students challenge both individual and environmental factors that affect their enrolment in STEM disciplines. Therefore, this chapter argues that persuasion principles can be integrated into technologies, and when female students use such technologies, they can develop positive attitudes toward STEM disciplines.

In the field of psychology and information technology, systems designed to change attitudes and behaviours are known as persuasive technologies (PTs). Consequently, Chapter 3 aims to understand how PTs can be used to change female students' attitudes towards STEM disciplines to increase their enrolment in STEM disciplines. The study conducted a literature review on existing PTs and PT frameworks to ascertain what has been communicated regarding the persuasive strategies, system features and technological platforms used to achieve attitude change. This chapter specifically reviews STEM-related PTs that have employed existing PT frameworks to determine how they employed the frameworks in their designs. This review uncovers the strengths and weaknesses of the existing frameworks and provides an opportunity for the study to deploy an upgraded framework.

The rest of Chapter 3 is organised as follows: Section 3.2 begins with a discussion on the concept of persuasion to accentuate its role in the education domain. Section 3.3 then looks at the concept of persuasive technology (PT) to understand the notion of integrating persuasion principles into technologies. This is followed by Section 3.4, which discusses the behavioural learning theory and how it supports the application of PT. Section 3.5 discusses different application areas of PTs and their successes. Thereafter, Section 3.6 discusses PT in the education domain, Section 3.7 discusses PT frameworks and how STEM-related PTs employ the frameworks, and Section 3.8 summarises the chapter.

3.2 THE CONCEPT OF PERSUASION IN THE CONTEXT OF THE STUDY

Miller (1980, p.34), defines persuasion as “an interactive process through which a given message alters an individual’s perspective by changing the belief or attitude that underlies that perspective”. This can be achieved using verbal, non-verbal or para-verbal cues (Ting, 2018). The art of persuading individuals can be dated back to ancient Greece, where rhetoric was taught to privileged Greek males as part of their education so that they knew how to change people’s moods, opinions or motives with public speeches (McKay, 2020). The ancient Greeks believed that persuasive speaking was central to sustaining a healthy society (McKay, 2020). Today, persuasion is a common phenomenon in the day-to-day interaction of humans. Politicians use persuasion to influence voters; likewise, sales personnel talk customers into buying products, and even parents employ persuasion to convince their children to take certain actions.

In the learning domain, it is often argued that teaching is an act of persuasion in that tutors and educators often have to reinforce or strengthen certain beliefs or attitudes in students to promote positive learning experiences (Nayir, 2017; Linnenbrink-Garcia et al., 2018; Steinmayr et al., 2019). For instance, keeping students undistracted and motivated throughout a lesson involves persuasion since some students are naturally inattentive or unmotivated and are easily distracted. Teachers have the responsibility to ensure that all students have the same opportunities, making persuasion a subtle part of everyday classroom interaction, in which positive learning attitudes and behaviour need to be reinforced. Hence, the argument for the use of persuasion to change female students’ attitudes towards STEM disciplines.

Some researchers might be unsettled by the notion of using persuasion to change female students’ attitudes towards STEM discipline because the terms persuasion and coercion are often mistaken as having the same meaning, whereas, in reality, their meanings are quite distinct (Kampik et al., 2018). While coercion uses the power of threat (even when subtly making the target feel they have no choice but to comply), the use of force, threat or manipulation to influence behaviour or attitude is not involved in persuasion (Jacobs, 2020). Taking the words to mean the same might wrongly create the impression that the use of persuasion to change female students' attitudes towards STEM disciplines would deprive them of their autonomy, when this is not the case, given the clear distinction between persuasion and coercion (Thomas, 1992).

Today, research in the field of psychology has identified several practical strategies to employ in other domains, including the education domain, to ensure that options available to female students are never obstructed, that they are aware of being intentionally influenced, and that such influence is in the best interests of the female students (Berdichevsky & Neuenschwander, 1999; Page & Kray, 2010; Jacobs, 2020). With the advancement in technological design, some of these strategies can be integrated into technologies to help female students build a positive attitude towards STEM professions and, consequently, enrol in STEM disciplines. The next section explains the concept of integrating persuasion into technologies.

3.3 THE CONCEPT OF PERSUASIVE TECHNOLOGY

The concept of PT is based on the idea that "through technology the attitude or behaviour of people can be changed using various persuasive strategies" (Behringer & Øhrstrøm, 2013, p.1). Persuasive strategies are converted into system features and are deliberately used when designing PTs to influence the attitudes or behavior of its users. This study intends to integrate various persuasive strategies into a technology for female students to use, thereby aiming to change their attitudes towards STEM fields, which would, in turn, increase their enrolment in STEM disciplines.

For example, the reward persuasive strategy is a popular strategy that builds on the learning approach to persuasion (Oinas-Kukkonen & Harjumaa, 2009). The reward persuasive strategy involves offering incentives to individuals as they progress in a task (Oinas-Kukkonen & Harjumaa, 2009), based on the premise that incentives would encourage individuals to accomplish a task. In a PT, the implementation of the reward persuasive strategy takes the form of game elements like users' status, badges, points and ranks. Female students who engage with a PT can be rewarded as they advance in behaviour-related tasks to keep them motivated to accomplish the task. Increasingly more persuasive strategies are being developed, as well as methods for converting these strategies into system features. Today, over 400 persuasive strategies (Orji et al., 2014) have been developed in the field of psychology that can be used to motivate female students. This study identified twenty-five persuasive strategies that most influence young female students, and the best ways to use them in technology for teaching STEM subjects are presented in the framework for designers to develop PTs that could change female students' attitudes towards STEM disciplines.

3.4 THE BEHAVIOURAL LEARNING THEORY AND PERSUASIVE TECHNOLOGY

A core characteristic of PT is its motivational power. The presence of influence strategies in a PT makes it capable of motivating female students towards the desired action. Motivation is central to learning because it affects the choices that students make about their education. Several researchers have empirically investigated the relationship between motivation and students' engagement; their findings have been consistent in showing that motivation impacts engagement (Nayir, 2017; Linnenbrink-Garcia et al., 2018; Steinmayr et al., 2019). The authors argue that motivated students are more likely to be highly curious, persevere for longer, produce higher quality effort, and learn more deeply.

The behavioural learning theory (BLT) forms a strong support for motivation in learning. This theory posits that all behaviour is caused by external stimuli and that learners adapt behaviour in response to external stimuli (Araiba, 2019). Before behavioural change can occur, people need to be stimulated. BLT operates on the principle of stimuli–response, as explained by Ivan Pavlov through the classical conditioning model, which posits that "when a naturally occurring stimulus and an environmental stimulus are repeatedly paired, the environmental stimulus will eventually elicit a response similar to that elicited by the natural stimulus" (Akpan & Kennedy, 2020, p.71). The famous Pavlovian experiment was used to elucidate this model. Pavlov conducted an experiment with dogs. He would present the dogs with food, and they would begin to salivate. He then began to ring a bell whenever the food was presented and after several repetitions, Pavlov realised that ringing the bell alone would make the dogs salivate without the food even being presented.

This experiment also explains human learning behaviour. In our day-to-day affairs, we are often exposed to different conditionings; for example, a teacher with a biased teaching style might condition a student to develop a dislike for the subject and even for school entirely. Conversely, the positive teaching behaviour of a teacher might have a positive impact on a student through the process of classical conditioning. Humans have a natural ability to learn, just as in Pavlov's experiment, where the dog's natural ability to salivate was successfully coupled with the ringing of a bell, so too, an environmental stimulus, such as a motivational push could eventually trigger humans' natural ability to learn when the learning process is correctly paired. In the context of this study, the motivational push of a persuasive educational technology is the stimuli.

In addition, the kind of teaching practices the BLT encourages promotes the affective component of learning. As discussed in Chapter 1, there is an affective component of learning which deals with the emotional aspect of learning, namely learners' interests, values, sense of belonging, and motivation for learning, all of which components are essential in learning. Which the brain supports the cognitive aspect of learning, BLT facilitates a passive learning behaviour, more like supporting the mind. The brain and the mind two different components that can and should work concurrently for learning to successfully take place. Given that BLT supports PTs' motivational powers, it follows that PT might potentially motivate young Nigerian girls to enrol in STEM disciplines. The next sub-section discusses the various application areas of PTs to shed light on how they have been used to address pressing societal issues in several domains.

3.5 APPLICATION AREAS OF PERSUASIVE TECHNOLOGY

PT has been applied in many domains, such as health, ecology, commerce, security and education. The health domain has been heavily impacted by research on PT. In a meta-analysis of 95 PT studies, 47.4% were designed to promote general well-being and prevent or manage illnesses (Hamari et al., 2014). *MotiMate* is one such PT designed to persuade users to maintain a healthy weight. Users receive suggestions on the kind of exercise, diet and social activities they should engage in to maintain a healthy weight, and if they abide by these suggestions, earn badges to decorate their accounts. Users with the most decorations are recognised, and the badges users earn serve as motivation to maintain a healthy weight (Brindal et al., 2016). *It'sTimeToEat* is another PT designed to promote healthy eating among children. Through the app, children adopt virtual pets to take care of. They feed the pets by daily uploading pictures of their meals. The application sends reminders and suggestions for food and healthy snacks to keep the pet growing and healthy.

Children whose pets grow healthily earn points. This way, children are encouraged to eat healthy meals and build a healthy mindset towards healthy meals (Pollak, 2010).

STD Pong is another interesting PT. It was designed by Ndulue and Orji (2018), to change risky sexual behaviour among African youths. The PT was modelled after the arcade game in which a player fights to defeat sexually transmitted diseases (STDs). The designers used an African storyline and character to make their audience better relate to the game. Players are rewarded with points and educated about how to prevent, manage, or treat sexually transmitted diseases as they progress in the game. The authors believe that the excitement players experience from being rewarded after defeating a sexually transmitted disease will reflect in the game players' real-world behaviour. PTs in the health domain have recorded successes. In a meta-analysis of 85 studies, 75% of the studies recorded positive results, 17% recorded partially positive results and 8% recorded negative results (Orji & Moffatt, 2016). In another meta-analysis of 45 studies, 42 recorded positive results, while three recorded negative results (Hamari et al., 2014). These findings indicate that PT has some potential to motivate individuals towards a desired behaviour.

PT has also found applications for promoting healthy ecological behaviours. Hamari et al. (2014) reported that 21% of the 95 studies reviewed were from the ecological domain. One of the prominent ecological challenges PT designers in this area have targeted is to promote energy conservation (Arendt et al., 2014). More eco-aware systems are being designed to reduce excessive electricity consumption. Taha et al. (2018) developed a persuasive system that helped the National Health Service (NHS) hospital in Midway, in the UK, reduce its electricity consumption. Aiming to reduce greenhouse carbon emissions and positively impact the environment, the app was designed to collect energy consumption data from various departments and display the data on a web interface so that staff could see the effects of their actions. This subtly persuaded them to refrain from excessive electricity use. This intervention reportedly helped reduce energy costs for the hospital by 20%. PT in the ecological sector, in general, has also recorded successes. According to Hamari et al. (2014), of the 20 studies reviewed, only one study recorded a negative result.

The use of PT to promote sales has also gained much attention among marketers (Romanova & Smirnova, 2019). Today, many businesses have websites that use persuasive cues to subtly turn visitors into regular customers. Prompts on commercial websites notifying visitors that certain products are almost sold out or indicating the number of sales made on a product are all nudges that can create a sense of urgency in the mind of a website visitor to purchase a product. Websites have also used reviews to promote sales; for instance, Adaji and Vassileva (2017), showed how Amazon reviews influence customers' perceptions of the effectiveness and credibility of products. Forty-four per cent of customers' decisions to continue purchasing products on the website were influenced by other customers' reviews. These reviews were also shown to improve customers' shopping experience. Other application areas of PT, such as security (Bawazir et al., 2016), and entertainment (Chow et al., 2017; Sobczak, 2019), have experienced steady growth over the past decade and have recorded successes. Like how PT has been used to improve other aspects of life, there is a prospect for its use in the education domain (Lucero et al., 2006; Gram-Hansen & Kristensen, 2013; Bech, 2013).

3.6 PERSUASIVE TECHNOLOGY IN THE EDUCATION DOMAIN

In the education domain, PT can be defined as tools used to promote desired learning attitudes or behaviour among students. For example, to address the decline in book reading among Chilean children, Lucero et al. (2006) developed an application aimed at persuading children between 8 and 11 years of age to read and write. They argued that the decline in reading among children has been a drawback to the personal process of developing their imagination. Their PET is a game-based PET where children create stories out of object that the game companion (Papelucho) finds. Another study by Ndulue and Orji (2018) designed a persuasive educational game aimed at promoting risky sexual behaviour change among African youths. They argued that the excitement experienced by players from being rewarded after defeating a sexually transmitted disease will reflect in the game players' real-word behaviour. That is, players will be motivated to defeat STDs in real-life. Bech (2013) developed a Persuasive application aimed at improving the learning of cultural heritage, at Kaj Munk Museum, through persuasive means. Their goal is to establish a virtual world, that serves to persuade the user to fulfil the museums wishes for better spreading knowledge and acknowledgement of the life and significance of Danish author and playwright Kaj Munk. They argue that the persuasive app will strengthen the chances of visitors leaving with a greater knowledge of Kaj Munk and his historical importance.

There is less research recorded in this area compared to others (Orji et al., 2018) despite its potential to bring about positive attitude and behaviour change among learners (Plass et al., 2013; Hsu et al., 2016; Marra et al., 2016; Orji et al., 2021). The available literature shows that PT in the education domain is designed to achieve different psychological outcomes: engagement, motivation, commitment, awareness, enjoyment, compliance, attitude and behavioural change. They appear in several technological channels: web-based applications, desktop applications, robots, SMS (short message services), games and virtual learning environments and have been guided by different theoretical frameworks: eight-step design, functional triad, and persuasive system design framework (Hamari et al., 2014). Despite the limited number of studies in the education domain, the literature search found a small number focused on STEM subjects. The next section reviews existing PT frameworks and how they inform the design of STEM-related PT.

3.7. FRAMEWORKS USED TO DESIGN STEM-RELATED PERSUASIVE TECHNOLOGIES

The review begins by discussing a framework and then how PT designers employ the framework in designing PT for STEM subjects. This study maintains that no frameworks provide design guidelines focused specifically on the education domain. The available frameworks are generic PT frameworks that do not focus on any specific domain. Based on the literature, there are three well-established and widely used frameworks for the design of PTs: The eight-step persuasive technology design framework, the functional triad framework, and the persuasive system design framework (PSD). Although these frameworks are old, they are the most established in the literarure.

3.7.1 The Eight-Step Persuasive Technology Design Framework

Fogg (2009b), proposed eight steps for designing PT, which is more like a generic software development cycle. Figure 3.1 is a diagrammatical representation of the framework (for clarity). These steps are explained below.

Step 1: Choose a simple behaviour to target.

The first step involves identifying the behaviour intended for the user to adopt. The target behaviour should be small, relevant and measurable. In this stage, the PT designer is expected to reduce a big attitude or behaviour change goal to tiny behaviour change objectives. Fogg claims that targeting too complex goals often leads to unsuccessful PTs.

Step 2: Choose a receptive audience.

The second step is to choose a receptive audience. According to the author, it is more apposite to select a willing audience at an early stage of the project and then expand the audience as successes are recorded. In addition, choosing an audience familiar with computer technology and enjoying the use of computer technology is paramount since the aim of the designer is to create a digital device. The author argues that targeting an unreceptive audience might slow down the design process.

Step 3: Identify potential barriers to the target behaviour.

The framework emphasises the need to identify factors that impede the performance of the behaviours. He proposed Fogg's behavioural model (Fogg, 2009a), which posits that three factors (motivation, ability and the trigger) can obstruct the behavioural change process.

Step 4: Choose the right technology channel.

Designers should select an intervention channel appropriate to the target behaviour and audience. How well the technological channel fits the intended audience and behaviour has a significant effect on the success of the persuasion.

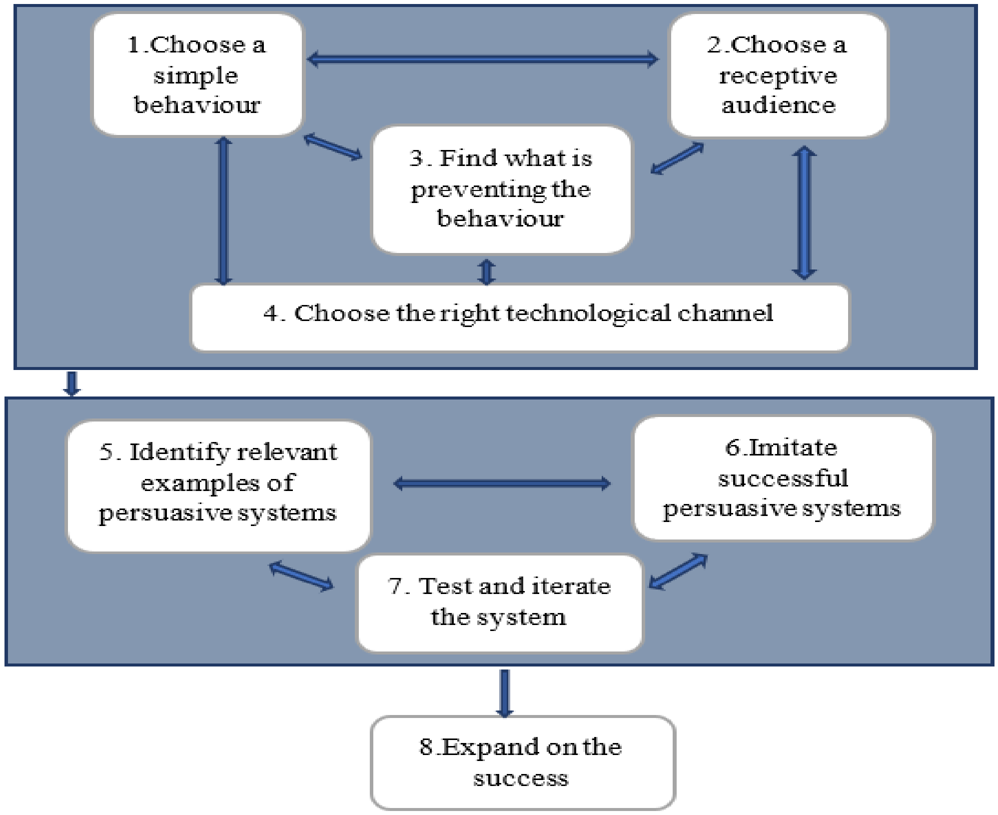

Figure 3. 1: The Eight-Step Persuasive Technology Design Process (Fogg, 2009b)

Step 5: Identify relevant examples of persuasive technology.

This step involves searching for PT design solutions from relevant successful PTs. According to the author (Fogg, 2009b), this increases the likelihood of the project succeeding. However, the author also agreed that it might be difficult to know whether or not a PT was successful since companies do not often share their data; in this case, he suggested making educated guesses.

Step 6: Imitate successful persuasive technology.

This step involves implementing the ideas identified in Step 5. Often, designers want to be innovative; however, using proven design ideas would accelerate the project and provide space for more layers of innovation.

Step 7: Test and iterate the system.

This step involves rapid trials of the prototype system. The test should take a few hours for responses to be assessed and a new test conducted. These tests are not meant to be sophisticated scientific experiments but rather quick trials that allow designers to see how users react.

Step 8: Expand on success.

The design should expand based on recorded successes. After a series of recorded successes in Step 7, the project can scale up and make the target behaviour more advanced. However, care should be taken not to upscale the behaviour too high. The scaling should be systematic, introducing only one or two variables at a time.

The literature search revealed that only a few studies have used the eight-step design framework to design PTs for STEM subjects. These studies are discussed to gather insights that would inform the design of the PET4STEM framework. Orji et al. (2018) developed a web-based PT aimed at encouraging learners to participate in online learning of biological science. They claimed that students were often distracted by other social activities and needed to be motivated to stay engaged with schoolwork to avoid failure or dropping out. They employed the eight-step design framework to guide the design of their PT.

Following the eight-step design framework, they (1) targeted a simple behaviour to increase engagement in online learning; (2) chose a receptive audience, which was first-year students in the university; (3) identified what distracted students from focusing on their courses and found it to be other social activities and gaming; (4) identified the correct technological channel by conducting a literature review, and identified web-based applications as the best-suited channel since the students were mostly gaming and socialising on the web; (5) identified the correct persuasive strategies by conducting a literature review and found strategies that would be ideal for their audience; (6) identified successful PT to imitate by conducting a literature review, and found Kaptein et al. (2012;) and Orji et al. (2017), relevant PTs to imitate; (7) tested their PT; and, finally, (8) intended to expand their target by introducing students from other classes and STEM courses.

There are major insights from the eight-step design framework and its execution by Orji et al. (2018) in terms of persuading female learners to enrol in STEM pathways. Firstly, it is importance to select a receptive audience for an attitude change program. Orji et al. (2018) selected first-year students. One possible explanation is that they are still fresh to the university system and have not yet been addicted to the distractions of the school's social events. This implies that to increase the number of women in STEM fields, it is critical to select individuals who have not yet fully embraced the STEM stereotype. Hence, the most responsive audience for this current study are young females in junior secondary school as indicated in chapter one of this study.

The eight-step design framework and its execution by Orji et al. (2018) also show that it is imperative to identify what prevents from the intended attitude or behaviour and select a technological platform that is best suited to the problem. In Orji et al. (2018) study, the technological platform was a web-based applications because the distraction was the frequent socialisation on the web. They did not choose a messaging application, for example, to resolve the distraction from the web. This informs the researcher that technological platforms closely related to the identified barriers to women's enrolment in STEM pathways should be employed in this study.

However, the eight-step design framework has its limitations. According to Oinas-Kukkonen and Harjumaa (2009), the eight-step design framework provides suggestions for the early stages of PT design but no in-depth suggestions for PT design. Wiafe (2016), argues that this framework might be useful for novice designers but not for experts because of its lack of technicality. Designers who follow this framework have to rely on other successful PTs for options of persuasive design principles to employ. This is not reliable as it might be difficult to determine whether or not a PT was successful since companies do not often share their data. Another limitation is that the framework did not provide any domain-specific design considerations, as in the case of Orji et al. (2018), whose PT was intended for the education domain, specifically for biological science students, yet the framework did not provide any pedagogical design considerations for the biology subject. Designers who follow this framework end up with PTs that lack domain-specific features.

3.7.2 The Functional Triad Design Framework

Fogg (2003), devised a functional triad framework that categorises PTs into three groups and suggests design principles to employ for each category. The categorisation is based on the different roles a PT could assume. These categories are (1) A tool: A PT is categorised as a tool if its role is to make a task easier, more structured, or quicker for the user to perform. When a task is simplified for users, it increases the likelihood of engagement and task completion. (2) A medium: A PT is categorised as a medium if its role is to allow users to simulate real-world situations. Simulations help users experience real-world situations that would have been difficult to experience; thus, users better understand concepts or can rehearse real-world situations that can provide motivating experiences. (3) A social actor: A PT is categorised as a social actor if its role is to mimic the social behaviours of humans. When technologies imitate human behaviours, users are likely to build a social relationship with them, and then it subtly influences them. According to the author, understanding the various categories of PT can better inform designers on the best forms they can design their PT to assume. Figure 3.2 is a diagrammatical representation of the categories.

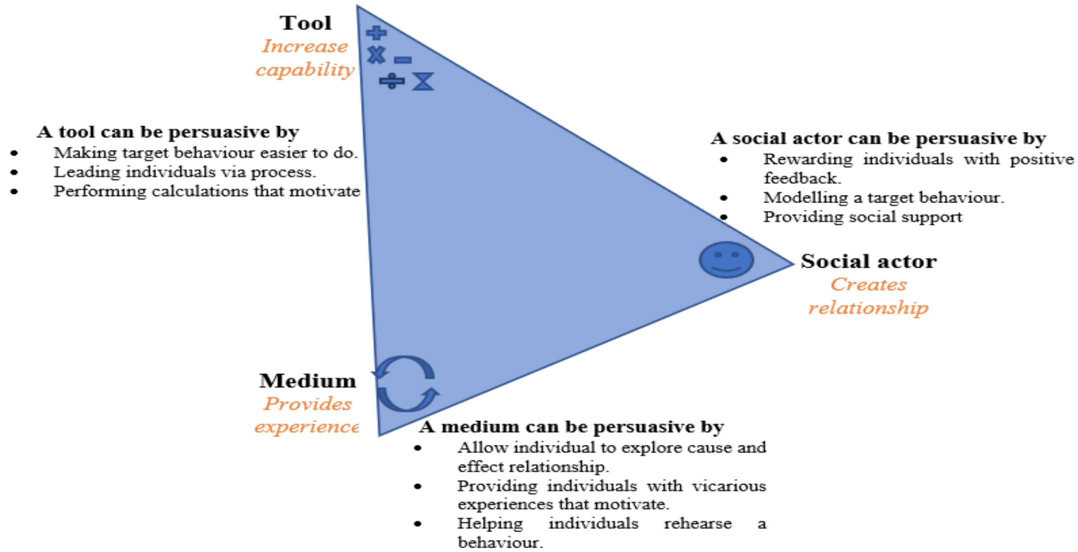

Figure 3. 2: The functional triad framework (Fogg, 2003)

The author provided persuasive design principles for each category, also known as persuasive strategies designers, can use to persuade their audience. Table 3.1 shows the categories discussed and the persuasive strategies that can be used for each category.

Table 3. 1: Fogg's persuasive strategies.

PT Category	Suggested persuasive strategies to employ
As a Tool	Reduction: A system can reduce or simplify complex tasks into simple tasks to help users perform the desired task.
	Tunnelling: A system can guide users in a predetermined direction.
	Tailoring: A system can present directed content to users based on their preferences.
	Self-monitoring: A system can provide a means for users to track their performances
	Suggestion: A system can provide prompts for users to aid them in completing a task
	Surveillance: A system can track users' performance so that they can share it with other users and be motivated by actions taken by others.
	Conditioning: A system can associate a reward with a task to motivate the user to perform the task
As a Medium	Simulation: A system can simulate real-world experiences to help users see the link between cause and effect immediately.
As a Social actor	Social role: A system can adopt a social role. (e.g., doctor, engineer or mathematician.) Psychological influence: A system can support feelings, empathy or emotions. Social dynamic: A system can support taking turns, praise for good work, answering questions or reciprocity.

The literature search shows more STEM-related studies that have employed the functional triad framework as a guide to designing their PT rather than the eight-step persuasive technology design process. For example, Bamidis et al. (2011)employed the functional triad framework to upgrade an existing learning management system (mEducator *MOODLE*) into a PT. Following the framework, they designed their PT as a tool and employed three of the suggested design strategies in the Tool category of the framework, namely Reduction, Tunnelling and Tailoring. The intended psychological outcome was to promote medical students' engagement with the LMS by simplifying search retrieval and reuse. The developers claimed that results from commonly used search engines were often overwhelming and irrelevant and could be discouraging to medical students whose study load was already overwhelming. Hence, they employed the functional triad framework to upgrade the LMS into a PT. Following the framework, the Reduction design principle was implemented by providing search results in the most basic way. A sophisticated algorithm decreased the search results' complexity for the students. The Tunnelling design principle was implemented by presenting the most applicable content suited to a specific topic. The Tailoring design principle was implemented by using metadata fields where students described their desired resources so that contents are matched to their culture, educational level and language. Thus, providing students with the most related results in the easiest form.

In Goh et al. (2012), the functional triad framework was also used as the underpinning guide to structure the SMS messages they sent to students. All seven persuasive design principles suggested in the Tool category of the functional triad framework were adopted by the authors. The authors asserted that newly enrolled information system students were often easily demotivated because of their study load and needed to build a more self-regulated learning approach. Hence, they designed a messaging system to promote the engagement and commitment of newly enrolled information system students and documented how they implemented some of the persuasive design principles. For instance, by following the Suggestion design principle instead of just reminding the student to review their textbooks, the SMS contained a suggestion of the chapter to review before each lesson.

By following the Tunnelling design principle, instead of just sending reminders to the students to submit their assignments on time, they set different milestones for the assignment and then send SMSs at the time they expect students to have reached a milestone. This way, students are periodically updated on the stage at which they ought to be to submit their assignments on time. By following the Tailoring design principle, instead of just reminding students to attend lectures, the messages sent to each student had their own tutorial time and tutorial room number. By following the Conditioning design principle, SMSs that included praises were sent to students whenever they reached a milestone. The authors reported a significant improvement in self-regulated learning among the students.

In Bertel and Hannibal (2015), the functional triad framework was used as a guide to evaluate the effectiveness of a PT used to promote interest in computer programming among 7th-graders. The PT was a programmable robot used in the teaching of STEM subjects. According to the designers, the technology (NOA robot) is now used by over 70 countries to teach computer science, both at primary and secondary schools and universities. Bertel and Hannibal (2015) were interested in determining how students viewed a robot and the implication of their perception of the robot on their motivation to learn computer programming. The students used choreography to create behaviours that were then tested on the NAO robot. The authors found that the students subconsciously categorised the robot as a social actor. They interacted with the robot as though it were a young person like them, using phrases like "come on my little chai-chi friend" and then positioning themself behind the robot to support it while waiting for it to perform the behaviour. These were attributed to the robot's small size and clumsy movements. The authors claimed that using the robot to promote interest in computer programming was very impactful.

The main strength of the functional triad framework is that it provides designers with suggestions of persuasive design principles to employ based on the category of their PT. The implication for this regarding motivating women to enrol into STEM disciplines is that the researcher has to be mindful of the persuasive strategy to be suggested in the framework as it has to be suited to the category that the PT assume. However, it still falls short of domain-specific design considerations. It also failed to describe how persuasive design principles can be converted into actual system features so that designers can easily operationalise the persuasive strategies in actual PT. Designers are faced with the bulk of work to convert persuasive design principles into system features, which can be very challenging. The persuasive system design framework was developed to address the deficiencies in the frameworks discussed so far.

3.7.3 The Persuasive System Design Framework

Oinas-Kukkonen and Harjumaa (2009), developed the persuasive system design framework (PSD) to address some of the constraints of the eight-step design framework and the functional triad framework. The authors started by dividing the design of PTs into three main stages: understanding key issues behind designing a PT, analysing the persuasive context behind the PT design and identifying design features that PT should possess. According to the authors, this approach provides a more structured design process and allows for a more in-depth discussion of system features and requirements. These stages are discussed below.

Stage 1: Understanding key issues behind persuasive systems.

Oinas-Kukkonen and Harjumaa (2009), postulated that PT design can only be successful if the designer first understands seven key issues; this statement is based on evidence from theoretical and empirical works. First, information technology (IT) is not neutral and will influence users in one way or another. Second, individuals want their worldview to be organised and consistent. Third, there are direct and indirect routes to persuasion; direct routes are used for individuals willing to evaluate persuasive information, while indirect routes are used for individuals unwilling or unable to evaluate the persuasive message. Fourth, persuasion is often incremental; hence, PTs should be designed to enable users to perform incremental tasks towards the target behaviour. Fifth, persuasion should be open; Sixth, persuasion should be unobtrusive, i.e., it should not prevent or distract its users from performing other tasks; and seventh, PTs should be useful and easy to use. Figure 3.3 is a diagrammatical representation of the PSD framework.

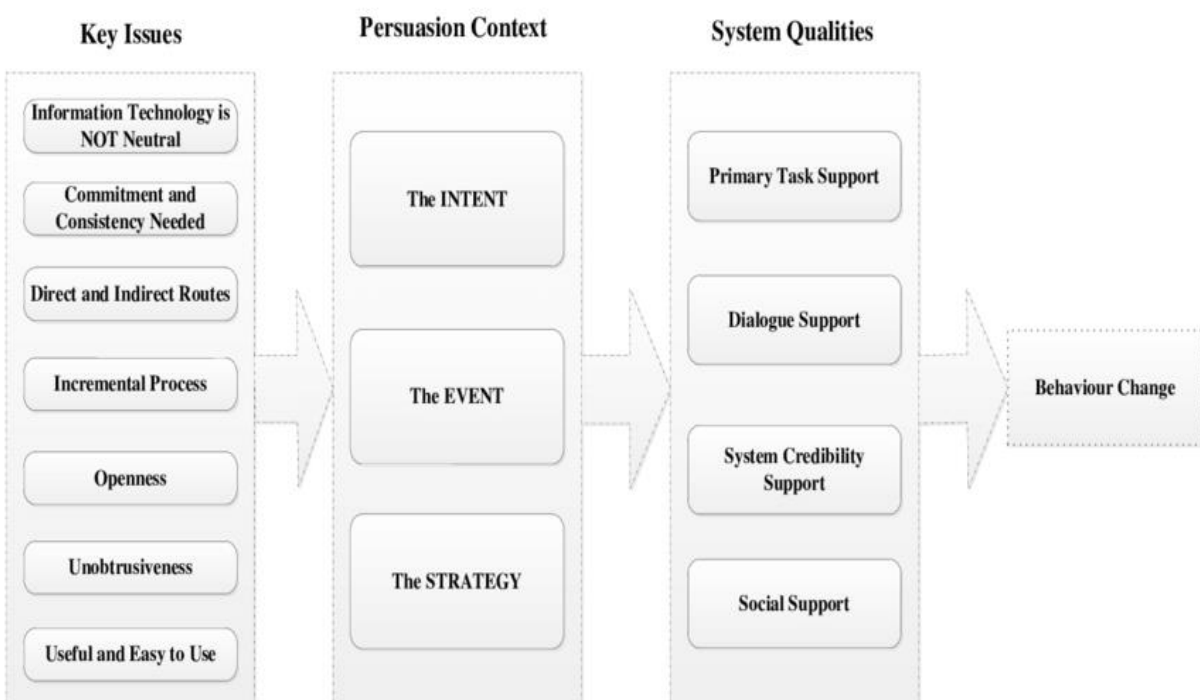

***Figure 3. 3: Persuasive System Design (PSD) Framework* (Oinas-Kukkonen & Harjumaa, 2009)**

Stage 2: Analysing the persuasion context.

Analysing the persuasion context means understanding the given circumstances around a persuasive event. The circumstances surrounding every persuasive event differ; as a result, designers need to understand the specific context for which the PT is to be designed. To achieve this, the authors proposed identifying the *intent* of the persuasion, understanding the *event* of the persuasion, and identifying the *strategies* to be used. Identifying the intent involves identifying the desired psychological outcome; understanding the event involves understanding the usage, user and technology contexts; lastly, identifying the strategies involves understanding the route to use and the message to serve for persuasion. After understanding all the above-mentioned, the designer can select the system design features to implement.

Stage 3: Selecting System Design Feature

According to the authors, the functional triad framework presented the design principles but did not explain how they would be converted to software requirements and then into system features. Hence, they went a step further to provide this by categorising the requisite qualities of a PT into four primary tasks: support, dialogue support, credibility support and social support. Primary task support allows users to perform the main tasks involved in accomplishing the target behaviour. Dialogue support transforms the task into an interactive process. Credibility support makes the task appear credible to the user. Lastly, social support offers social support to the users. Each of these system qualities has specific design principles; for every design principle, the authors suggested a software requirement and system feature. Figure 3.4. summarises the qualities.

The PSD framework has been used as a guide in several studies, but STEM-related studies are still scarce. The literature search found a STEM-related study by Star et al. (2017). The authors developed three different PTs: a game, an interactive web-based application and a 3D desktop simulation application. Their PT was developed to build competence and interest in STEM subjects among 9th-graders, and they employed the PSD framework as a conceptual guide. In the game platform, students solved various mathematical puzzles as they interacted with the game environment. The suggestion strategy was employed to provide hints to students who asked for assistance in finishing any of the puzzles. In the interactive web-based module, through animated characters, students learned about the brain. The personalisation strategy was employed by allowing students to progress through the module at their own pace. In the desktop application, the simulation strategy was employed to explain mathematical concepts and their applications to everyday life, thereby allowing students to notice the connection between cause and effect immediately.

In employing the PSD framework, Orji et al. (2018), identified four design principles to be integrated into their web-based PT. Three principles are from the social support category: *social comparison*, *social learning*, and *competition*, and a fourth from the primary task support category, *personalisation*. Their PT was aimed at encouraging learners to participate in the online learning of biological science. To operationalize the personalization persuasive strategy, a user study was conducted to identify the persuasive strategy to which a student would be most susceptible to. To implement the "social comparison" design principle, their web application provided students with a means to compare their grades with others. Furthermore, their web application provided aggregate for all students to implement the social learning design principle, for every student to see the outcome of performing the behaviour. Lastly, their web application provided a leaderboard displaying a student's position relative to the best 10 students to implement the competition design principle.

The major contributors to the PSD framework were the additional persuasive design principles it provided, and the system features it suggested. These provide the researcher with more options of persuasive design principles to employ in the framework and reduce the work of converting the principles into design elements. This also implies that the research can adapt the design element to ones that will be most suited to motivating young female students in Nigeria to enrol in STEM disciplines. Despite these strengths, the PSD framework still has some limitations, as do the previous frameworks. Thus, persuasive design principles are important aspects of a PT; however, other important components comprising a PT were not addressed by the PSD framework. Designers need to be aware of the limitations of the desired behaviour and understand the problems surrounding the domain for which the PT is designed. Further, there should be awareness of the technologies suited to the target user and domain.

System qualities	Persuasive strategy and example requirements	Example implementations
Primary task support (to enable users to carry out the main tasks)	Reduction: Break down complex activities into manageable steps.	PT for healthier eating lists proper food choices at fast food restaurants.
	Tunnelling: Provide means for action that brings them closer to the target behaviour.	Smoking cessation PT offers treatment options after an interactive test about how addicted a user is.
	Tailoring: Provide content to users based on their preferences	PT for recovering alcoholics tell stories that are close to user's story.
	Self-monitoring: Provide means for users to track their performance	Heart rate monitor presents user's heart rate and exercise duration.
	Personalizing: System should provide personalized content and services for its users.	Arguments most likely to be relevant for the user presented first on a professional Web site rather than in random order.
	Simulation: Provide real-world experience via virtual environments	Website presents before-and-after pictures of those who have lost weight
	Rehearsal: Providing means for rehearsing the target behaviour.	A flying simulator to help practice for severe weather conditions
Dialogue support task (ensure that the persuasion process is interactive)	Praise: Use praise via text, image, or sounds for feedback.	PTs can send automated text-messages for reaching individual goals.
	Reward: Provide virtual rewards to users as they progress in tasks.	Heart rate monitor gives virtual trophies if fitness program is followed
	Reminders: System should provide remind users of their goals	Caloric monitoring PT sends text-messages to users as daily reminders.
	Suggestion: System should suggest that users carry out behaviours during the system use process.	Application for healthier eating habits suggests that children eat fruits instead of candy at snack time.
	Similarity: System should imitate its users in some specific way.	Slang names are used in an PT to motivate teenagers to exercise.
	Liking: System should have a look and feel that appeals to its users.	PT encouraging children to care of pets put pictures of cute animals.
	Social role: System should adopt social roles.	Virtual specialist to support interaction between users and specialists.
System credibility (ensures that the PT appears credible to the user)	Trustworthiness: System should provide information that is truthful.	PT provides information related to its products not biased advertising.
	Expertise: System should provide competent information	PT provides information about their core knowledge base.
	Surface credibility: System should have competent look and feel.	A limited number of, and a logical reason for, ads on PT
	Authority: System should refer to people in the role of authority.	PT quotes an authority, such as a statement by government health office
	Third-party endorsement: Provide backing from respected sources.	Web site refers to its reward for high usability.
	Verifiability: Provide means for system to be verified if needs be.	Claims on a PT are supported by offering links to other web sites.
Social support (persuading users using social influence)	Social learning: Enabling users learn by viewing activities of others.	A shared fitness journal in a PT for encouraging physical activity
	Social comparison: Comparing a user's performance with other users	Users can share and compare information related to their physical health and smoking behavior via instant messaging application.
	Normative influence: System should provide means for gathering people who have the same goal and make them feel norms.	A smoking cessation PT shows pictures of new-born babies with serious health problems due to the mother's smoking habit.
	Social facilitation: Providing means for discerning other users who are performing the behavior.	Users of PT for learning can recognize how many co-students are doing their assigned homework at the same time as them.
	Collaboration or Cooperation: Enabling users collaborate in the behaviour change process	The behavioral patterns of overweight patients are studied and sent to a central server where it can be analyzed at the group level in more detail.
	Competition: Allowing users to compete to achieve their target.	Online competition, such as Quit and Win.
	Recognition: Publicly recognizing the performance of users.	Names of awarded users, like "stopper of the month," are published.

***Figure 3. 4 Persuasive System Requirements and Example Implementations* (Oinas-Kukkonen & Harjumaa, 2009)**

In short, designers must be aware of two critical design structures: situation and method. A designer's understanding of conditions, such as learner, content, context and constraints, is reflected in the situation. Consequently, the designer selects the instructional method(s) best suited to the situation. According to West et al. (2020), educational technology frameworks must consider both the learner and the learning environment. The PSD framework is generic, making it unsuitable for providing such detailed suggestions. This, in turn, makes the framework appear focused only on providing suggestions for persuasive principles.

A context-specific framework would be more realistic by way of reducing the complexity of the audience and the domain. Choe et al. (2011), designed a PT framework specifically for promoting healthy sleep behaviour. The level of design guidelines presented was granular; it addressed the peculiarities surrounding healthy sleep technologies, relieving designers of the task of resolving domain-specific issues. Table 3.3 summarises the strengths and weaknesses of the reviewed frameworks and the studies that employed the frameworks, alongside the psychological outcomes, technological channels and strategies used by the studies.

Table 3. 2: A summary of the frameworks and the studies reviewed.

Framework	**Strengths**	**Weakness**	**Study**			
			Author	**Affective outcome**	**Technology**	**Persuasive principle**
Eight-step design framework	Provides suggestions for early-stage PT design.	No suggestions for persuasive design principles. No suggestions for user and use context.	(Orji et al., 2018)	Engagement	Web-based application	None from the framework

Functional triad framework	Provides means for categorising PTs. Provides persuasive design. principles.	No suggestions for actual system features. No suggestions for user and use context.	(Bamidis et al., 2011)	Engagement	LMS	Reduction, tunnelling, and tailoring.
			(Goh et al., 2012)	Engagement, commitment	SMS	All the strategies in the framework
			(Bertel & Hannibal , 2015)	Interest	Robot	Similarity, social companion.
PSD	Provides persuasive design principles, software requirements, and actual system features.	No suggestions for user and use context.	(Star et al., 2017)	Interest, competence	Game, web-based app, desktop app	Suggestion, personalisation, simulation.
			(Orji et al., 2018)	Engagement	Web-based application	Personalisation, social comparison, social learning, competition.

The limited number of STEM-related PTs indicates ample opportunities and room for more studies. Hence, there exists a need for more context-specific frameworks for designing and evaluating PTs. To the best of the researcher's knowledge, no STEM-related PT has been designed targeted at young female Nigerian students.

3.8 SUMMARY

This chapter reviewed the most well established and widely used frameworks used to design PTs as well as STEM-related studies that employed the frameworks in their design. The chapter presents the argument that these frameworks fall short of providing context-specific guidelines for specific persuasion contexts, making them appear focused only on providing suggestions for persuasive principles. The study determined that a problem-specific framework should be developed to address this limitation. This present chapter also explained the realisation that for a framework to be focused on STEM enrolment by female students, designers need to be aware of two critical design structures: situation and method. The situation involves issues surrounding the limitations of the desired behaviour and the problems surrounding the domain for which the PT is designed. The method involves the instructional method(s) best suited to the situation and the technologies suited to the target user and domain. The next chapter presents a conceptualisation of the framework based on the literature reviewed so far.

CHAPTER 4: CONCEPTUAL FRAMEWORK

4.1 INTRODUCTION

The previous chapter presented a literature review on persuasive technology (PT). It looked at how PTs could be used to increase female students' enrolment in STEM disciplines. It was determined that existing frameworks for designing PTs were generic (Oinas-Kukkonen & Harjumaa, 2009; Wiafe, 2016; Murillo-Muñoz et al., 2021). Hence, a problem-specific framework needs to be created to resolve this constraint. The conceptual foundation that directs the creation of a PT framework specifically designed to motivate young female students to enrol in STEM pathways is covered in this chapter.

According to Yearworth and White (2013, p.54), a conceptual framework is a "synthesis of interrelated concepts, components or variables which emerged from literature and help in solving the research problem". Adom et al. (2018) define a conceptual framework as an idea emerging from reviewed literature on how a problem can be solved. This study considers the conceptual framework as a structure consisting of the components and their relationship that convey the researcher's understanding of why young female students opt for non-STEM professions over STEM professions and how to develop a persuasive educational technology for STEM (PET4STEM) framework that designers can use to create PTs to motivate young females to opt for STEM professions.

According to Collins and Stockton (2018), a conceptual framework is not the actual framework but rather a conceptualisation of the final framework, and a well-defined conceptual framework helps researchers "focus on their assertions as to the remedies of the problem defined" (Yearworth & White, 2013). In this conceptual framework, the researcher identifies and synthesises the relevant components in the study and describes how they individually contribute to solving the research problem.

4.2 THE CONCEPTUAL FRAMEWORK OF THE STUDY

This study draws on Lent's framework of social constructive career theory (SCCT) (Lenta & Brown, 2019), which has shown relevance in understanding students' interests and choices of academic disciplines (Duttaa et al., 2019; Chan, 2020). The theory emphasises the influence of particular internal and external factors on academic choice. SCCT posits that the decision to choose a career path emerges from the interest in such a career path and that interest builds from a set of individual variables (self-efficacy and outcome expectation) formed through exposure to different learning experiences and environmental factors (Abdullahi & Chimbo, 2023).

This study also draws on the theory of reasoned action (TRA) (Constanze, 2021) which posits that students' academic choices can be predicted by their attitude toward choosing an academic pathway and how they think other people will view them if they choose the pathway (subjective norms). The TRA agrees with the SCCT in that subjective norms reflect the influence of the external environment on an individual's decision-making or actions, while attitude reflects individual character. Both theories emphasise the influence of both external and internal factors on students' choice of academic disciplines (Abdullahi & Chimbo, 2023).

This study also leans on the behavioural learning theory (BLT) (Araiba, 2019), which argues that people need to be stimulated before a behavioural change can occur. BLT was explained in Ivan Pavlov's famous experiment with dogs, whereby he presented the dogs with food, and they would salivate (Araiba, 2019). He then began to ring a bell whenever the food was presented, and after several repetitions, Pavlov realised that ringing the bell alone would make the dogs salivate even without the food being presented. This experiment also explains human learning behaviour. In our day-to-day affairs, we are often exposed to conditions that shape our future attitudes and behaviour. At school, a teacher with a biased teaching style might condition a student towards developing a dislike for a subject—even for school entirely—and vice versa (Abdullahi & Chimbo, 2023).

From the BLT, the researcher realised that humans have a natural ability to learn, so an external stimulus such as a motivational push can eventually begin to trigger humans' natural ability to learn different concepts when the learning process is stimulated correctly, just as in Pavlov's experiment where the dogs' natural ability to salivate was successfully paired with the ringing of a bell and the same result was obtained. This theory implies that a motivational push in a persuasive educational technology can serve as an external stimulus for female students to participate in STEM professions.

These theories provided a foundation for arguing that specific external factors influence students' attitudes towards STEM professions, and it is these attitudes towards STEM that determine whether they choose to enter STEM fields in future. Students should be subtly persuaded to change their attitudes through these influences to counter the effects of such factors. Hence, a persuasive educational technology (PET) tool is regarded as a suitable tool to help increase the number of women following STEM professions. Figure 4.1 presents the conceptual framework that guided the design of the actual PET4STEM framework.

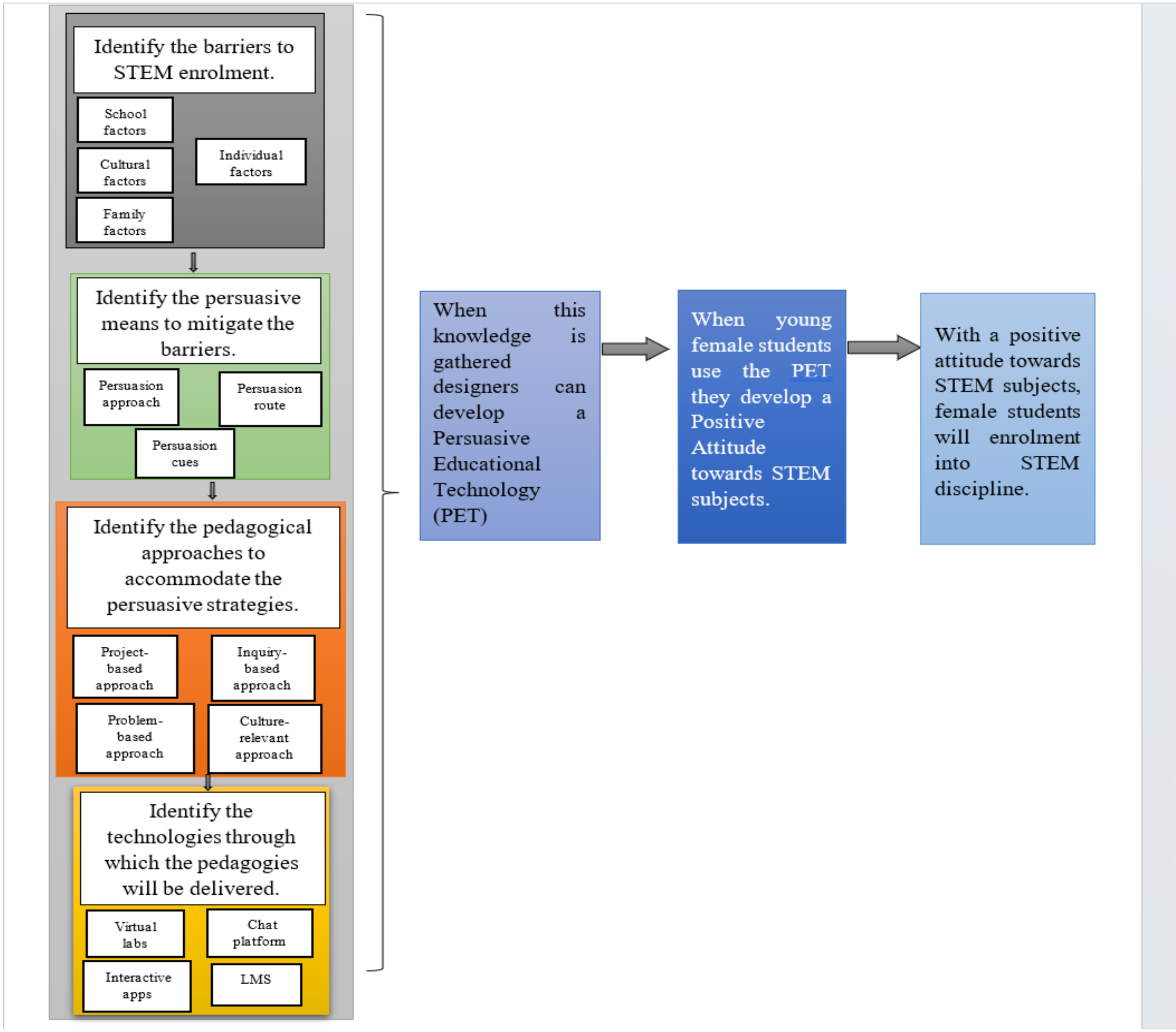

Figure 4. 1: The Conceptual Framework of The PET4STEM Framework

As illustrated in Figure 4.1, designers need to be aware of four key components to design such PETs. These components are:

1. Barriers to enrolling in STEM pathways: Mintz and Aagaard (2012), assert that educational technology designers striving for attitude or behaviour change should be aware of the factors surrounding adopting the desired attitude or behaviour. They are crucial to the overall success of a technology. This is because very little can be accomplished in solving a problem if the causes of the problem are not first identified. In this study, designers must be aware of the barriers to female students' enrolment in STEM disciplines. None of the existing frameworks mentioned in Chapter 3 identified the limitations or barriers to the desired behaviour towards which they are motivating their audience (West et al., 2020). Hence, the PET4STEM framework fills this gap. This component of the PET4STEM framework provides designers with the knowledge of the barriers to young female students choosing STEM disciplines in school.

2. Persuasive knowledge: In Chapter 3, the study determined that the PET designer's objective was to bring about attitude change among young Nigerian female students. and the persuasion approach to attitude change is a viable means of achieving this. This made persuasion central to the PET4STEM framework. Oinas-Kukkonen and Harjumaa, (2009), emphasise that the type of persuasion communication designers employ is subject to the audience and the content for which a PT is designed. What motivates adults might not motivate teenagers, and what motivates in the health domain might not motivate in the education domain (Petty & Cacioppo, 1986). Hence, designers need to be aware of persuasive strategies suited to female students and STEM subjects. Although the existing frameworks mentioned in Chapter 3 provided suggestions for persuasive strategies, they were not specific to any problem. Accordingly, the PET4STEM framework fills this gap. The persuasion knowledge component of the PET4STEM framework provides designers with persuasive strategies to which women are more susceptible.

3. Pedagogical knowledge: Archambault et al. (2022), stress that the creation of educational technologies involves thinking critically about teaching, learning, and the entire objective for which the technology is being designed. Furthermore, West et al. (2020, p.597), argue that "a solid foundation about the user context, the use context, and the learning content separates educational technology designers from general application coders". The reason is that the curricula, learning objectives, how instructional contents are sequenced, and how ideas are interconnected differ between disciplines. In this study, designers had to be aware of pedagogies that best accommodate persuasion communications, pedagogies that are effective in delivering STEM subjects, as well as

pedagogies to which female students would be highly responsive. The existing frameworks mentioned in Chapter 3 were generic and thus did not provide any context-specific considerations. Hence, the PET4STEM framework fills this gap. The pedagogical knowledge component of the PET4STEM framework provides designers with the knowledge of instructional methods, feedback methods and classroom management that would effectively motivate young Nigerian females to enrol in STEM disciplines.

4. Technology knowledge: Fogg (2009), argues that choosing the best technological channel for delivering the message is crucial in PT design. Designers must know which technologies can accommodate the teaching and learning strategies for the effective delivery of instructional content. The technologies should also be such that female students would embrace them, and one that persuasion communications could be integrated into (Abdullahi & Chimbo, 2023). Again, the existing frameworks mentioned in Chapter 3 did not provide suggestions of technologies that designers can use. Hence, the PET4STEM framework fills this gap. The technological knowledge component of the PET4STEM framework provides designers with potential technologies and ways to employ the technologies effectively to promote STEM enrolment among young female students in Nigeria. Figure 2 presents the conceptual framework that guided the design of the PET4STEM framework.

The remaining sections of the chapter discuss in more detail how these components interrelate in the PET4STEM framework with respect to solving the research problem.

4.3 FACTORS INFLUENCING ENROLMENT IN STEM.

The Lents' framework (Lent & Brown, 2019) of social constructive career theory (SCCT) and the theory of reasoned action (TRA) (Ajzen & Fishbein, 1980), were used in this study to understand the factors influencing students' decision to enrol in STEM. These frameworks led to the realisation that environmental influences, namely family influence, school influence, and cultural influence (Guo et al., 2019; Plasman et al., 2020; EL-Deghaidy, 2021), affect individual character, which, in turn, affects attitudes towards STEM subjects. The upcoming sections discuss how these factors affect the enrolment of female students in STEM fields with citations to supporting theories and empirical research.

4.3.1 Family Influence

According to the literature, students' perception of themselves, their values, opinions and feelings about activities can all be influenced by the expectations, norms and values their families uphold (Lloyd et al., 2018; Chevalier, 2002; Korpershoek et al., 2021). This argument is consistent with the review of women's educational motivation in Chapter 2, which revealed they were motivated to attend school to meet family expectations and adhere to their norms and beliefs (King et al., 2012; King, 2016).

The literature demonstrates that family influences might be unintentional when children identify with their parents' practices in their very early years. For instance, a survey of related literature (Sheldrake, 2018; Guo et al., 2019; Plasman et al., 2020), revealed that children aspired to professions similar to those of their parents because they were their children's primary models to emulate and live up to. Family influences might also be deliberate insofar as parents communicate their expectations to their children. Halim et al. (2017) and Burusic et al. (2018), argue that highly educated parents and those in professional occupations tend to communicate the positives of their careers to their children, probably because they have had good experiences and want their children to experience the same levels of satisfaction.

This finding aligns with claims by Bandura (1971), that the advantages enjoyed by highly educated parents in professional occupations tend to be passed on to their children, which happens from generation to generation, keeping children in the same socioeconomic strata as their parents. Moreover, researchers contend that the decision to pursue a particular career path occurs in the context of social interaction and cultural influences based on Vygotsky's sociocultural theory. According to Vygotsky (1978), humans create knowledge based on their interactions, experiences and interpretations of their sociocultural environment. Based on this literature, this study understands that familial factors can shape the identities, values and attitudes of female students towards STEM education, which, in turn, can affect the probability of their choosing a STEM career path.

It is imperative to provide designers of PET to promote female students' enrolment in STEM disciplines with the family practices, norms, values and expectations of female students for them to be accommodated in STEM learning (Khan & Grimm, 2020; Hoffman et al., 2021). Engaging students in meaningful STEM activities that consider their family values and expectations creates a powerful connection between classroom learning and diverse family circumstances, allowing them to see STEM education as a way of meeting family needs and expectations. Mauricio et al. (2019) and Lachney et al. (2021), suggest that doing so might make STEM education more relevant and encourage more STEM activity participation. Chapter 6 details the results of interviews to identify and investigate the familial factors affecting junior secondary school students' enrolment in STEM paths. These results were included in the PET4STEM framework.

4.3.2 School Influence

According to Taber and Akpan (2017, p.15), "Schools differ widely in resources, such as teacher quality, teaching style, robustness of curriculum, classroom culture, available textbooks, and laboratories ". These factors, as indicated by the SCCT (Lent et al., 1994; Lenta & Brown, 2019) and prior studies (Samuelsson & Samuelsson, 2016; Awan et al., 2017; Mau & Li, 2018), can affect a student's STEM educational engagement and career aspirations. For instance, even though this is not done on purpose, several academic works assert that STEM teachers tend to favour male pupils in their teaching methods (Terrier, 2016; Sovansophal & Shimizun, 2019). The authors argue that overestimating the abilities of male students, overly praising their successes, and giving examples that portray scientists, engineers and technologists as men are all forms of attention bias favouring boys that could negatively impact young women's' sense of belonging in the same environment regarding STEM.

These behaviours by teachers may seem trivial; however, they can subtly discourage female students' interest in STEM (Bertrand & Duflo, 2017; Carlana, 2019; Papageorge et al., Gershenson & Kang, 2020), because teachers play an important role in student's learning process (Papageorge et al., 2020). Students see teachers as their mentors (Gershenson et al., 2016), guides or role models, and as such, their behaviours can result in uneven learning motivation and outcomes among students (Griffith, 2010; Carlana, 2019). In addition, excessive focus on theory and less attention to practical works in STEM classrooms have been issues of concern for researchers (Milner-Bolotin, 2018). This aspect contributes to many students struggling to link what they learn in class to the real world around them (Benabentos et al., 2021; Mystakidis, 2021). Moreover, there is also the issue of not linking STEM subjects to ideas and topics that interest students (Marosi et al., 2021). Consequently, STEM subjects appear boring and irrelevant (Dare et al., 2021). For these reasons, the researcher believes that some school characteristics affect how many female students choose to major in STEM fields and that these elements should be uncovered, and designers of PET must be alerted about them to promote female students' enrolment in STEM fields. Chapter 6 details the results of the interviews to identify and investigate the school factors affecting junior secondary school students' enrolment in STEM paths. These results were included in the PET4STEM framework.

4.3.3 Cultural Influence

Cultural factors include the customs, values, beliefs and ideologies of a particular community or group. The influence of cultural factors, such as societal norms (Moshfeghyeganeh & Hazari, 2021), and societal beliefs (Nagdi & Roehrig, 2019; Cong et al., 2021), on female student enrolment in STEM has been documented by previous studies. Vygotsky's sociocultural theory (Vygotsky, 1978), agrees with this claim, which posits that individuals learn by interpreting their internal reality based on their observations of the external reality around them. Students perceive and internalise cultural norms and beliefs, which drive their motivation for particular career paths (Cross & Madson, 1997; Chevalier, 2002). The authors state that in some cultures, due to people's perception of both physical and non-physical differences between males and females, certain activities are perceived as more efficiently accomplished by one gender or the other.

According to social role theory (Eagly & Wood, 2012), such inferences predispose men and women to different gender roles in society. Women often choose jobs with regular hours that are less physically demanding to fulfil their domestic and caregiving responsibilities better, in contrast with men who, typically being bigger, stronger and faster, tend to choose more physically demanding jobs. These cultural beliefs and expectations have far-reaching effects, including influencing women's decisions to choose STEM career paths (Kuzhabekova & Almukhambetova, 2020; Chan, 2022). Hence, Chapter 6 details the results of the interviews to identify and investigate the cultural factors affecting junior secondary school students' enrolment in STEM paths. These results were included in the PET4STEM framework.

4.3.4 Individual Influence

The influence of family, school and culture discussed above are all environmental factors that work in synergy to shape a student's characteristics (Suhendi, 2018; Mukhalalati & Taylor, 2019; Scavarelli et al., 2021). However, an individual's characteristics directly influence their decision-making (Lent et al., 1994). Hence, throughout children's growing years, they are continually exposed to a variety of activities at school, at home and in society, which subsequently mould their self-perception (Spelke, 2005; Meece et al., 2009). Their perceptions of their ability to solve problems, for instance, can be constructed by verbal persuasion from schoolteachers, peers, or parents (Sovansophal & Shimizun, 2019; Hoffman et al., 2021), which, in turn, informs their decision to choose or not choose to continue with a task. Malleable individual factors, such as a student's perceived self-efficacy, self-esteem, goals, outcome expectation, ability-belonging, social belonging and values, have been well documented by prior studies as being influenced by the surrounding environment (Cheryan et al., 2017; Rahman et al., 2018). Consequently, this researcher argues that individual characteristics play a significant role in the decision to enrol in STEM disciplines and proceeds to investigate these factors among junior secondary school students. These results were included in the PET4STEM framework.

4.4 ATTITUDE TOWARDS STEM

Attitude towards STEM describes the resulting responses from students towards STEM enrolment due to the influence of environmental and individual factors. The perception that STEM is more object- than people-oriented is reserved for a select group of people who do not identify with STEM (Cheryan et al., 2017; Makarova et al., 2019). According to Su et al. (2015), Eccles and Wang (2016), Kuhn and Wolter (2010), and Dare et al. (2021), all affective responses to STEM are by-products of environmental influences to which students are exposed. These responses include the belief that STEM is for inherently intelligent people and that it is boring.

Some existing research claims that women's choice of non-STEM paths is not due to a lack of intellectual capability but rather subjective perceptions of STEM, which stem from interaction with their surroundings (Kuhn and Wolter, 2020; Cong et al., 2021). According to Dada (2017), the emotive rather than the cognitive aspect of learning is to blame for why fewer women choose STEM-related fields. The literature informed that learning constitutes cognitive and affective components. The cognitive component deals with the mental (intellectual) aspect of learning, by which the brain evaluates, analyses, synthesises and creates knowledge. The affective component involves feelings, emotions and attitudes.

In general, attitude refers to a specific way of thinking or feeling towards an object or an evaluative judgement formed by a person about something (Schlenker, 1978; Regan & DeWitt, 2015). Frameworks on enrolment behaviour view attitude as a construct that precedes and directs our decisions and choices. Under their theory of reasoned action, Fishbein and Ajzen (1975), explain that a student's enrolment behaviour can be predicted by their attitude towards performing the behaviour and how they think other people would view them if they exhibited such behaviour. This implies that the low enrolment of females in STEM fields might be a result of their negative perceptions of STEM, which are assumed to be caused by relevant environmental and personal factors (Regan & DeWitt, 2015). Strong support exists for research focusing on the emotional component of STEM learning to encourage enrolment (Regan & DeWitt, 2015; Stelter et al., 2021). These research findings suggest that employing the attitude change approach, also known as the persuasion approach, is a viable means of increasing female students' enrolment in STEM paths. This is where the persuasion knowledge component becomes relevant.

4.5 PERSUASION KNOWLEDGE

Persuasive strategies are influence strategies that have been developed to convince an individual to behave in a desired manner without coercion. Today, over 400 persuasive cues developed by researchers in the field of psychology are used for persuasion (Orji et al., 2018). Chapter 3 discussed persuasive strategies related to the learning domain, but those strategies were used on a different audience. For this study, designers need to be aware of the strategies that should be employed to change young female students in Nigeria's attitudes towards STEM. Chapter 6 details the results of interview and focus group sessions that identified the persuasive strategies to which junior secondary school students are susceptible and were used to develop the PET4STEM framework.

4.6 PEDAGOGICAL KNOWLEDGE COMPONENT

Once strategies are identified, designers must apply teaching methods that would accommodate such strategies. Jaipal and Figg (2010), also suggest that designers must have knowledge of a variety of appropriate instructional methods that can be delivered through technology. The pedagogical knowledge component of the PET4STEM framework provides designers with teaching approaches that work well for delivering STEM subject content to female students.

The relevance of this component in the PET4STEM framework is supported by the literature review conducted in Chapter 3, which identified two problems as challenges associated with students' engagement with STEM subjects in the classroom, namely STEM concepts not being connected to the real world (Seron & Silbey, 2004; Zastavker et al., 2006; Benabentos et al., 2021; Mystakidis, 2021), and the absence of a link between STEM subjects and ideas or topics of interest to students (Khan & Luxton-Reilly, 2016; Marosi et al., 2021).

It was argued and supported by data that students had difficulty understanding and remembering STEM subject matter when there was no connection to the real world (Cox et al., 2018). This situation was ascribed to giving too much weight to theories and not enough to putting such theories into practice (Milner-Bolotin, 2018). Moreover, the failure to consider students' interests and values when structuring the contents of STEM subjects made STEM subjects appear irrelevant to students (Brown et al., 2019; Marosi et al., 2021).

In response to the aforementioned reasons, the researcher examined STEM teaching strategies that could address these challenges. The extensive research conducted over the past ten years indicates that instructional strategies might affect students' motivation and engagement in STEM studies (Ottenbreit-Leftwich et al., 2021). The study's findings led to the identification of four strategies that could be employed in persuasive educational technologies to encourage female students' interest in, engagement with, and enrolment in STEM fields. Project-based learning, problem-based learning, inquiry-based learning and culturally relevant learning are further components of the four approaches.

Knowledge of pedagogical approaches suited to resolving problems around women's engagement with STEM subjects is an important aspect of PTs designed to motivate young women to enrol in STEM disciplines. This aspect is missing from the reviewed frameworks. Having this component in the framework developed in this study makes the framework richer for designers.

4.6.1 Project-Based Learning

Project-based learning (PjBL) is a student-centred approach that allows students to solve real-world problems by participating in contextually rich projects (Rugh et al., 2021; Qisthi & Arifani, 2020). Because the issues derive from the real world, students might connect the principles to their everyday lives and put the theoretical concepts they have learnt in class into practice (Benabentos et al., 2021; Mystakidis, 2021), making engagement more meaningful (Kazun & Pastukhova, 2018; Qisthi & Arifani, 2020).

4.6.2 Inquiry-Based Learning

Inquiry-based learning is a student-centred approach whereby students are encouraged to pose questions, explore the phenomenon, discover and share ideas rather than the teacher telling them what they need to know (Attard et al., 2021; Stevenson et al., 2021). According to Cairns and Areepattamannil (2019) and Csaba et al. (2021), this learning approach can make STEM education more engaging and relevant for students when they are guided to ask questions about the topics that interest them. Sockalingam et al. (2011), and Lin and Tsai (2021), also claim that it can make STEM learning more interesting for students.

4.6.3 Problem-Based Learning

Problem-based learning (PBL) is a teaching method that allows students to collaborate to gain knowledge and skills by investigating and responding to authentic and engaging open-ended questions (Fidan & Tunce, 2019; Tan, 2021). Open-ended questions allow students to brainstorm various possible scenarios to arrive at the best solution, as well as to decide the sequence and style to employ in solving the problems (Khoiriyah & Husamah, 2018). According to Hidayati et al. (2019), and Malmia et al. (2019), open-ended questions give students autonomy over their learning, which is crucial for better retention of STEM concepts and subsequent information retrieval.

4.6.4 Culturally Relevant Learning

Culturally relevant STEM education, as presented in Chapter 2, emphasises the significance of acknowledging and accommodating students' cultural norms and values in all aspects of teaching and learning STEM (Gay, 2018; Smith et al., 2022; McClain & Neri, 2022). When STEM learning is linked to the cultural norms or values of students, it creates a connection between students' cultural practices and the objectives of STEM education (Khan & Grimm, 2020; Hoffman et al., 2021), hence, students regard STEM education as a potential way of meeting family or societal objectives, and thus STEM learning becomes relevant to them (Beltran-Grimm, 2021). It is assumed that these pedagogical approaches can change how students experience learning and engage with STEM subjects.

4.7 TECHNOLOGICAL KNOWLEDGE COMPONENT

After the instructional approaches have been identified, designers must be alerted of potential technologies through which the teaching approaches can be delivered and the powerful ways these technologies can be employed to change how female students experience learning STEM subjects and their perception of STEM professions. The technological knowledge component of the PET4STEM framework provides designers with effective technologies for STEM teaching to motivate young female students in Nigeria to enrol in STEM disciplines. The relevance of this component in the PET4STEM framework derives from the literature review conducted in Chapter 3, presenting technologies used in persuasive educational technologies. Technologies such as online interactive learning, like chat applications, forums, simulation, augmented reality, virtual reality and gaming, were identified as potential STEM learning platforms. In Nigeria, young women have had very little to no interaction with such technologies for learning purposes; hence, they may be keen to use them.

4.8 SUMMARY

This chapter discussed the conceptual framework of the study; it identified the main components of the study and discussed how they interrelate in solving the research problem. The conceptual framework was based on the understanding that environmental factors and individual factors collaborate to influence students' attitudes towards STEM subjects, which, in turn, influence their decision to enrol into STEM disciplines. Because attitude is an affective component, the attitudinal change approach, also known as the persuasion approach, was proposed to counter the effect of external and internal factors to engender a positive attitude towards STEM in students.

Persuasive educational technology was specifically proposed as possessing the potential to produce the desired attitude towards STEM. Three components embody this tool, namely persuasion, education and technology. The persuasion component in the conceptual framework is relevant to understanding how a change in attitude could be achieved in the learning domain. The educational component is relevant to identifying STEM teaching methods that would enhance STEM learning experiences, while the technology component is relevant to identifying technological platforms that could enhance how students experience learning and engage with STEM.

For the persuasion component, the researcher reviewed the most widely used persuasive strategies in the education domain and how they are used to persuade learners. For the education component, the researcher reviewed STEM instructional approaches and identified effective approaches, namely project-based learning, inquiry-based learning, problem-based learning and culturally relevant learning that could provide students with a better learning experience in STEM subjects. Regarding the technology component, the chapter identified chat platforms, simulations and virtual laboratories as potential technological media through which to teach STEM and promote engagement and, subsequently, enrolment. The study submits that if these concepts, components and factors are considered in the design of a PET, it could promote a positive attitude towards STEM and, in turn, increase young women's enrolment in STEM disciplines. The next chapter present the research methodology.

CHAPTER 5: RESEARCH METHODOLOGY

5.1 INTRODUCTION

Chapter 4 presented the conceptual framework of the study. The chapter discussed the researcher's understanding of the important components PET designers should consider when designing PETs to promote junior secondary school female students in Nigeria to pursue STEM disciplines. This chapter is the research methodology; it describes how the research was conducted.

According to Saunders et al. (2019), research undergoes different systematic stages involving various techniques to address a research problem. Crucially, the techniques used in the different stages must align well for the research findings to be reliable. This study adapts the research onion model developed by Saunders et al. (2019), to present a well-structured research methodology. This model explains the stages of research by using the analogy of peeling an onion down to the bulb, which is hidden beneath layers of overlapping onion skins. The authors emphasise that one skin must be removed before proceeding to the next and finally reaching the bulb. The research methodology of this study is discussed by following Saunders' research onion, as illustrated in Figure 5.1.

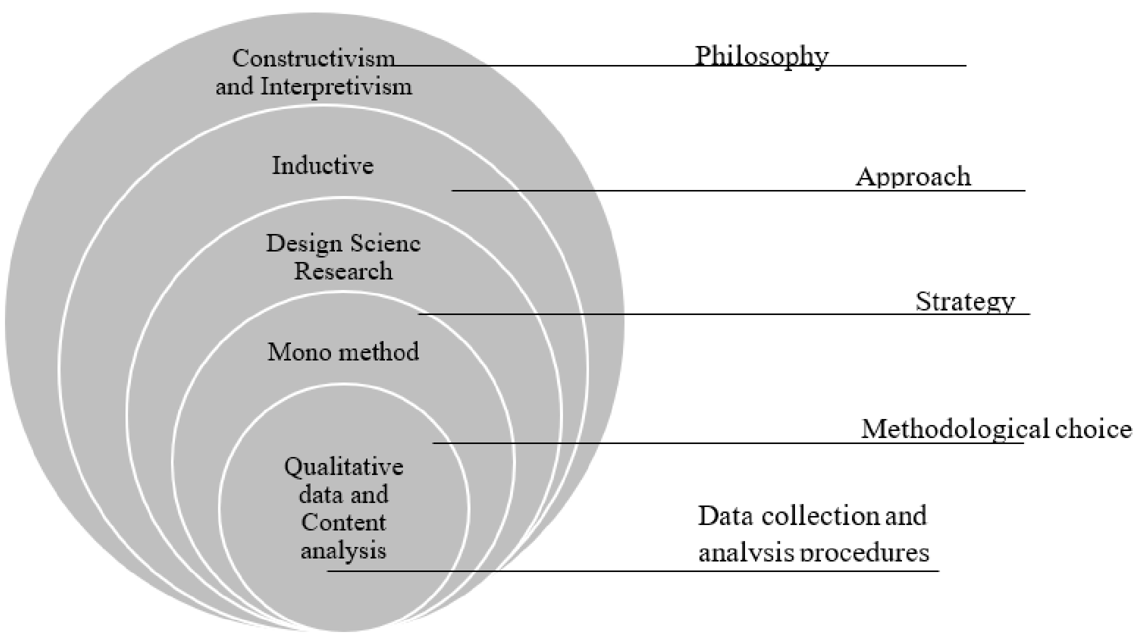

Figure 5. 1: Research process adapted from Saunders et al. (2019)**.**

As shown in Figure 5.1, Step 1 entails adopting a research philosophy; Section 5.2 discusses the constructivist and interpretivist philosophical stances with which the study aligns. Step 2 involves selecting a research approach; the study adopted an inductive research approach, and Section 5.3 discusses why the study aligns with this approach. Step 3 involves choosing a research strategy; the study adopted design science research (DSR), which is discussed in Section 5.4. Step 4 entails selecting a methodological approach; Section 5.5 discusses the mono-method and why it is appropriate for the study. Step 5 entails determining the data collection and analysis technique; Section 5.6 describes the qualitative data collection techniques utilised, while Section 5.7 describes the content analysis technique and how it was used in the study.

5.2 RESEARCH PHILOSOPHY

Selecting the appropriate technique to employ in a research study requires an in-depth understanding of the principles that determine how such techniques are deployed and interpreted. McGregor (2018), refers to these principles as the philosophical stance guiding the research. In Bairagi and Munot (2019), research philosophy refers to the different ways of seeing the world and conducting research. Creswell (2007), states that a researcher's philosophical perspective or worldview underpins their choice of research approach and strategy, and data collection, analysis procedure and data interpretation. According to the literature, existing philosophical doctrines can be distinguished by considering the ontology and epistemology of each (Kivunja & Kuyini, 2017; Pickard, 2018; McGregor, 2018; Bairagi & Munot, 2019).

Ontology is concerned with the nature of reality; that is, what exists as reality and what units constitute reality contains two dominant positions: objectivism and constructivism (McGregor, 2018). Despite acknowledging the existence of objectivism, which alludes that reality and its meaning exist independently of their actors and there is only one reality that everyone experiences, this study aligns with constructivism, which holds that reality, and its meaning are socially constructed by their actors and are constantly changing. As a result, there are numerous versions of reality, and everyone subjectively experiences different instances of reality (McGregor, 2018; Bairagi & Munot, 2019). The justification for this chosen paradigm was the researchers' beliefs that:

- The Research participants, like all social beings, have different milieus and thus, their experiences differ.
- Unlike physical phenomena, research participants and their social environs are in constant change; therefore, the researcher must observe and interpret opinions, feelings and perceptions based on specific social contexts.

For these reasons, the study selected constructivism as the ontological stance of the study. Epistemology is concerned with how knowledge is obtained and the most valid ways to investigate knowledge (McGregor, 2018). Within the epistemological philosophical underpinning, there are two dominant positions: positivism and interpretivism (Kumar, 2019; Kothari & Garg., 2019). This study adopted an interpretive position to analyse and interpret the qualitative data collected during the development and evaluation of the PET4STEM framework. Interpretivism is concerned with subjectivity in knowledge discovery (Bairagi & Munot, 2019). To wit, it advocates for an empathic understanding of how research participants perceive a situation; thereby, the voices and roles of a researcher and respondents have a bearing on the interpretation of the results, unlike in positivism, which is concerned with the discovery of generalisable facts and universal laws by relying solely on natural science methods. The reasons below justify why the researcher chose interpretivism:

- The researcher's own belief is that the research participants and their social worlds, unlike physical phenomena, are diverse and, as such, cannot be reduced to law-like generalisations.
- This study investigated abstract phenomena, such as the participants' perceptions, feelings, attitudes and behaviours; therefore, the positivist paradigm, which employs rigorous scientific methods, might not adequately address such research, but interpretivism allows a deep understanding of phenomena that cannot be explicitly measured.
- This study required the researcher to interact with the participants to understand each participant's reality. Interpretivism advocates interacting with participants in their naturalistic setting for them to be comfortable relaying their experiences. The researcher needs to delve into the participants' natural environment to fully answer the research questions, which is a more practical method of gathering contextually rich information.

- Interpretivism allows the research findings to be influenced by human interpretations.

5.3 RESEARCH APPROACH

This study aligns with the inductive research approach whereby observations are made, and data collected to explore reality without making prior assumptions (Frey, 2018b), while also acknowledging a deductive research approach where presumptions are made and then tested (Azungah, 2018; Young et al., 2019).

The reason for choosing the inductive approach was that the assumptions of prior studies might not necessarily concur with those of this current study's audience (Makarova et al., 2019; Banchefsky et al., 2019; Gana et al., 2019; Ugwuanyi & Okeke, 2020; Lent et al., 1994). Moreover, the reality regarding this situation is constantly changing. Hence, the present study did not adopt these presumptions; rather, new data was collected from a cohort who have never been investigated for this purpose to explore their reality and identify patterns and present solutions for other researchers within similar contexts to explore further. Another justification for the fitness of the inductive approach for this research is that inductive research aligns well with constructivist and interpretivist paradigms under which a researcher embarks on a study with an open mind because they believe that reality is dynamic.

5.4 RESEARCH STRATEGY

A research strategy is an overall plan of action for a researcher to follow in conducting research systematically and on schedule to produce valuable and publishable results (Primecz, 2020). Even though the researcher recognised other research strategies described in the literature (Bairagi & Munot, 2019; Primecz, 2020), it selected the design science research (DSR) strategy to guide its framework design and the case study strategy for data collection. Table 5.1 summarises the existing strategies identified in the literature and their applicability in the current study.

Table 5. 1: Research Strategy

Research strategy	Description	Applicable in study
Grounded theory	Research that develops a theory grounded on observations made during the research.	No
Ethnography	Research that studies the culture/behaviour of an ethnic group or any defined group over a long period.	No
Action research	Research that solves a problem by practically involving role-players within the community of practice.	No
Case study	Research that studies the characteristics of a real-life instance	Yes (For data collection)
Design Science research	Research that develops an artifact	Yes (For framework design)
Survey research	Research that collects data from an entire population or a very large sample of people by asking questions.	No

A case study is a strategy for investigating a phenomenon by focusing on one instance of it (Primecz, 2020). It offers a rich, in-depth description and insight into that instance. The research strategy for a case study includes studying the instance in its natural setting, considering relationships and processes, and using multiple sources and methods (Triangulation) to gather data (Brocke et al., 2020). A case study strategy was chosen for data collection in this study because it was not feasible to collect data from the entire Nigeria due to time and funding constrain. As a result, a state in Nigeria, Kano State, was selected for the research sampling. Critics argue that case studies only pertain to the specific instance analysed, limiting their generalizability. To respond to such criticism, this study ensured that the participants sampling was a good representation of Nigeria. It was necessary for the researcher to have a good representation of Nigeria because the study aims for its framework to be used in similar contexts across Nigeria. A more elaborate discussion of the data collection method is done in section 5.6 of this study.

DSR is a research strategy popular among the engineering, architecture and information systems disciplines (Primecz, 2020). It focuses on the creation of socio-technical artifacts to change existing societal circumstances into the desired (Perna, 2017; Evon et al., 2020; Brocke et al., 2020). The rationale for choosing DSR is its multiple iteration phases, which ensure rigour and relevance in artifact design and development (Brocke et al., 2020). Its iterative phases provided a well-structured plan of action through which the PET4STEM framework was redefined several times until a satisfactory result was achieved.

5.4.1 The Different Outputs of Design Science Research

A DSR artifact can take different forms: concepts, models, methods, instantiations and theories (Hevner et al., 2004; Gregor & Hevner, 2013). As a construct, the DSR project produces novel concepts identified or developed by the researcher and used to describe phenomena in the problem domain (Gregor & Hevner, 2013). As a model, the DSR project produces descriptions of the relationships between the different constructs in the problem domain (Gregor & Hevner, 2013). When a DSR project generates a set of steps that can be followed to solve problems, it is regarded as a method, but when it develops a physical artifact that operationalises components, constructs, models and methods for solving an identified problem, it is considered to have produced an instantiation (Gregor & Hevner, 2013). Lastly, when a DSR develops a set of statements about the relationships among constructs or concepts that aim to describe or enhance understanding of the phenomena being studied or to predict it, it is said to have developed a theory (Gregor & Hevner, 2013).

The research output of this study is an instantiation because the PET4STEM framework consists of components to guide PT designers on what to consider when designing applications to produce the desired attitude change in their audience.

5.4.2 Design Science Research Process Model and its Application in the Study

The DSR process model encapsulates the phases necessary to undertake a DSR project. Hevner (2016) believes the DSR process model distinguishes it from other design strategies. The model defines four cycles: relevance, design, rigour and impact. Figure 5.2 is a diagrammatical representation of the DSR four-cycle process model. The upcoming sections below explain how the four-cycle process model informed the design of the PET4STEM framework.

1. The Relevance Cycle: The relevance cycle is concerned with establishing the relevance of the DSR artifact to the immediate application environment. The study conducted an extensive systematic literature review in Chapter 2 to establish the relevance of the PET4STEM framework to the study's audience (junior secondary school girls in Nigeria), whereby several of the reviewed studies revealed the need for interventions targeting increasing the number of female students enrolling in STEM disciplines in Nigeria (Ekine & Abay, 2017; Baird, 2018; Reich-Shackelford, 2018; García-Holgado et al., 2019; Hanson & Krywult-Albańska, 2020; Nevin, 2020; UNESCO, 2020; Card & Payne, 2021).

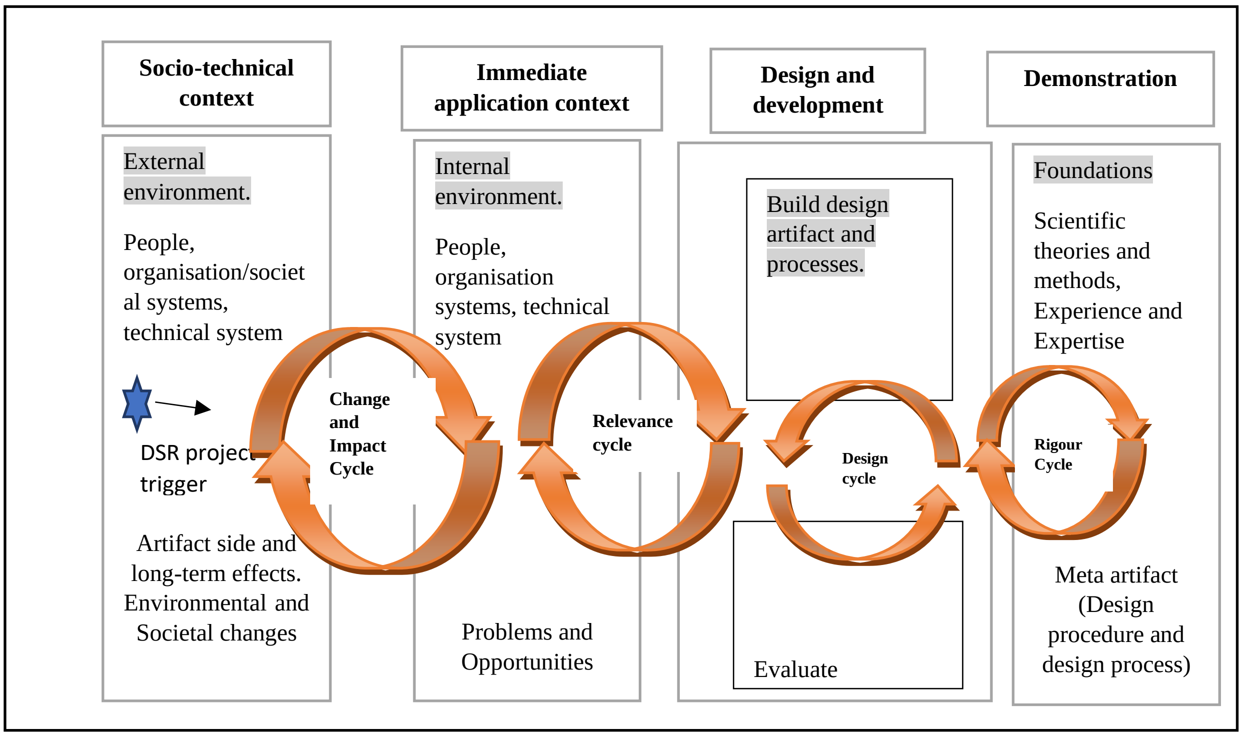

***Figure 5.2: DSR four-cycle view adapted from* (Drechsler & Hevner (2016).**

2. The Rigour Cycle: The rigour cycle emphasises the need to base the artifact on a strong and relevant knowledge base to ensure that the artifact is indeed a contribution to knowledge and not a repetition of previous design (Hevner, 2016). To establish rigour in the study, the researcher commenced by ensuring that the study's conceptual framework emerged from reviewing an extensive range of empirical literature and well-established theories relevant to the study, such as social cognitive career theory, the theory of reasoned action and the evaluation likelihood theory. These theories provided a robust theoretical base for the components of the PET4STEM framework. To ensure design rigour, after the initial PET4STEM framework had been developed,

experts in STEM professions in Nigeria were involved in reviewing, evaluating, and validating the framework design before a final PET4STEM framework was established. Consequently, to ensure rigour in the PET tool design, educational technology designers inspected the tool's use-case and the software used to develop the tool to ensure they are suitable for the intended purpose. This ensured that the framework and the tool were indeed an innovation.

3. The Design Cycle: The Design Cycle is concerned with the artifact's actual design and evaluation. This cycle contains a set of iterating activities called DSR methodology (DSRM) that guide researchers through the construction and evaluation of an artifact (Hevner 2016). Sub-Section 5.4.3 discusses these activities and their application in the design of the PET4STEM framework in more detail.

4. The Impact Cycle: The Impact Cycle is concerned with the researcher's awareness of the constantly changing needs and values of the external environment, which can affect the impact of the DSR project on the immediate environment. The external environment is the much wider environmental domain surrounding the immediate application domain of the DSR project.

The immediate application context of this study is junior secondary school female students in Nigeria, while the external environment includes the community surrounding the female students, the families of the female students, as well as their schools. Owing to the impact cycle, the study continually checked on the needs of the external environment so that the impact of the project remained relevant to the female students. Predictions from the existing literature indicated that even upon the study's completion, there would still be a huge demand for STEM personnel and the need for interventions to help get more female students to enrol in STEM disciplines to help fulfil the demand (Agboola, 2021; Feijoo & Rodriguez, 2022). Being aware of the dynamics of the external environment helped the study ensure that the DSR project's output remained relevant to the female students.

5.4.3 Design Science Research Methodology And its Application in the Study

The DSR strategy provides six sets of activities to guide researchers in producing valuable DSR projects. These activities are problem identification, objectives definition, design and development, demonstration, evaluation and communication (Gregor & Hevner, 2013; Drechsler & Hevner, 2016). Figure 5.3 presents a diagrammatical view of how these six steps were concretised in the study; their application in the study is discussed fully in the upcoming subsections.

5.4.3.1 Identifying the Research Problem.

This step involves identifying the research problem. For this study, Chapters 2 and 3 reviewed extant literature and identified the problem of the absence of frameworks to guide the design of PTs to motivate young female students in Nigeria to enrol in STEM disciplines. The study determined that a framework would contribute to reducing the shortage of STEM skills in Nigeria by providing PT designers with the knowledge to design effective PETs.

5.4.3.2 Defining the Objectives of the Solution.

This step involves defining how a problem could be solved and what specific criteria the solution should meet to solve the problem. Chapter 3 identified that designing a context-specific PET4STEM framework addressing the peculiarities relevant to young female students and STEM education, in contrast with the generic frameworks available in the literature, would enhance the design of PTs targeted at motivating females to enrol in STEM disciplines. As a result, the literature reviewed in Chapters 2 and 3 led to the emergence of a conceptual framework in Chapter 4. In the conceptual framework, it was indicated that designers need to have knowledge of the factors that influence young females learners enrolment into STEM disciplines, the persuasive strategies to which female learners are more susceptible, the teaching and learning approaches that can accommodate the persuasive strategies and are suited to teaching STEM subjects, and the technologies that can accommodate the teaching strategies for effective delivery of the STEM instructional contents. As a result, the framework offers context-specific design suggestions for motivating young female learners in Nigeria to enrol in STEM disciplines using the aforementioned important facts.

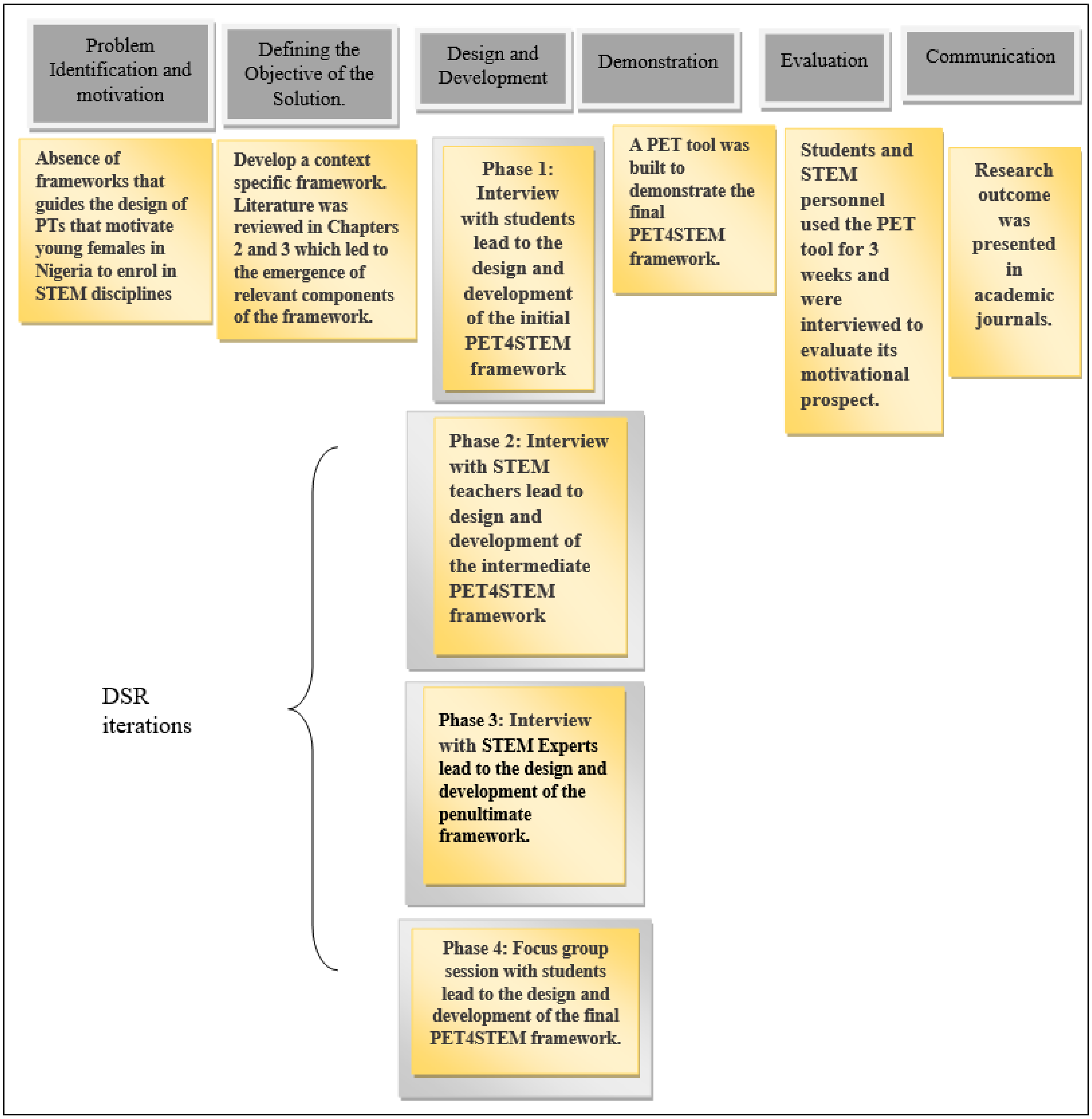

Figure 5. 3: Applying the* Drechsler & Hevner (2016)*DSR methodology in the study.

5.4.3.3 Design and Development

In this step, the actual design and development of the PET4STEM framework occurred. Due to the iterative steps in the DSR methodology, the framework went through four design and development phases before a final PET4STEM framework was presented.

(i). First design and development phase: This phase involved interviewing junior secondary school female students and inquiring about the four key components identified in the conceptual framework. The information gathered from these students was used to develop the initial PET4STEM framework.

(ii). Second design and development phase: After the first interview with the students, the product developed was presented to the STEM teachers. The teachers were asked if they resonated with the information in the framework and if they had any input. Their responses were used to redesign the initial PET4STEM framework, which led to the development of an intermediate PET4STEM framework.

(iii). Third design and development phase: After the interview with the STEM teachers, the developed product was presented to the STEM experts, who were asked if they resonated with the information in the framework and if they proposed any adjustments. The information gathered from the STEM experts were used to develop a penultimate PET4STEM framework.

(iv). Fourth design and development phase: After the interview with the STEM professionals, the framework was finally presented to the students in a focus group session. The students were asked if they resonated with the information in the penultimate framework and if they wanted anything to be adjusted. The information gathered from the focus group session with the young female students were used to redesign the penultimate framework. This led to the development of the final PET4STEM framework.

5.4.3.4 Demonstration

This step involves using the designed artifact to solve one or more instances of the problem to prove that the artifact works. In this study, a PET tool was developed, students and STEM personnels were recruited to use the tool for 3 weeks. This was to demonstrate that the components of the framework can be implemented in an actual application.

5.4.3.5 Evaluation

Evaluation involves assessing a product to ascertain if it provides a solution to the problem. In this study, the students and STEM personnel that used the PET tool were interviewed to evaluate its motivational prospects. The results indicated that the framework met its objective. The Attention, Relevance, Confidence, and Satisfaction (ARCS) model was used to analyse the responses. The responses from students and STEM experts indicated that the PET tool has potential to engage and motivate learners. See section 7.7 and 7.8 of Chapter 7 in this study.

5.4.3.6 Communication

This step involves communicating the DSR project to the relevant audience and stakeholders. This study's research contributions were published in accredited academic journals (Abdullahi & Chimbo, 2023).

5.5 METHODOLOGICAL CHOICE

Researchers have three methodological choices, namely mono-method, mixed-method and multi-method (Haig, 2018; Rutberg & Bouikidis, 2018). The methodological choice of this study is the mono method. The reason why it is mono method is because this research collected one data type. The data collected in this study was qualitative, no quantitative data was collected. According to Haig (2018), qualitative data produces rich and subjective findings which can be further explored in a similar setting. The qualitative data gathered for this study was sourced from interviews and a focus group session. The next section elaborates on the qualitative data collection technique used.

1. Interviews

Frey (2018a) asserts that interviews are used in research assessing attitudes and perceptions because they allow the researcher to collect self-reported data from participants that accurately represent their perceptions. Leavy (2017) also states that interviews allow interaction with participants and afford a deeper understanding of phenomena. This study used interviews to collect data. Due to the direct nature of the interviews, the researcher was able to observe how participants responded to the questions. The researcher obtained key information from their expressions, gestures and tone of voice. Structured, semi-structured, and unstructured interviews are three types of interviews (Flick, 2018; Durdella, 2019). In structured interviews, the questions are set before the interview and followed without introducing new questions during the session. In unstructured interviews, the questions are not set beforehand; they emerge during the interview. In semi-structured interviews, the questions are set beforehand, but new questions may emerge during the interview.

This study utilised semi-structured interviews. During the interview sessions, follow-up questions emerged to gain a deeper understanding of what was being asked. Following the DSR methodology, the interviews were conducted with students, teachers and STEM experts. Each interview session lasted approximately 45 minutes.

2. Focus Groups

Focus groups are a qualitative data-gathering technique whereby a researcher assembles a small homogenous group of individuals to discuss specific topics informally under the guidance of a moderator. The study used a focus group to identify and extract relevant and interesting reactions beyond what was obtained during the interviews. The researcher conducted a focus group session lasting approximately 40 minutes with the female students. Assembling the female students in a focus group saved the researcher time instead of organising another series of one-on-one interview sessions. The next section explains how the study sampled the participants in the study.

5.6 PARTICIPANT SAMPLING

This section discusses the sample technique used to select the participants for the study. It begins with the motivation behind sampling. A brief explanation on what target population, accessible population, and study sample means will justify the need for sampling in this study.

The target population refers to the entire group of people that is of interest to the researcher i.e., the group of people that the researcher intends to generalize their findings to (Thacker, 2020). It is also referred to as the theoretical population. This study's target population is young female students in junior secondary schools in Nigeria. A research's target population is usually very large and difficult to manage. Data for 2023 from the Nigerian statistics authority (National Bureau of Statistics, 2019b) estimated the total number of girls in junior secondary school in Nigeria to be 2,786,332. This is a very huge population. This is where the accessible population comes to play.

The accessible population, also known as the study population, is the group of people that the researcher can actually study (Thacker, 2020). It is usually a subset of the target population that the researcher can get access to. But with Nigeria been a large country, with 36 states, it was difficult to have access to female students from all the states in the country, especially with the COVID-19 interstate travel restrictions at the time of data collection.

Kano State in the north, however, was readily accessible to the researcher. It has an estimated population of 10 million inhabitants (National Bureau of Statistics, 2019b). Aside from being accessible to the researcher, it is also the most populous and the most culturally diverse states in Nigeria. Hence it made a good representation of the target population. However, the total number of female students in junior secondary school in Kano State is estimated to be 234,230 in public schools and 126,934 in private schools (Kano State Secondary School Board, 2021). This number is also very large and may prove unmanageable for the researcher, hence, a more manageable universe was required. This is where study sample comes to play.

Study sample refers to the selected people chosen from the accessible population to participate in the study, which is usually a representation of the target population. Whatever findings are made from this sample can be generalized to the target population if the research ensured that the sample is representative of the target population (Asiamah, Nestor; Mensah, Henry Kofi; Oteng-Abayie, 2017)(Thacker, 2020). To get the study sample for this research, the researcher made use of a local government area (LGA) in Kano State. Each state in Nigeria is divided into local government areas (LGAs). Kano state has 44 LGAs. To have a more manageable universe, one LGA was selected for the study: Tarauni local government area.

The reason for choosing Taurani is that it is more populated and cosmopolitan than all other LGAs in Kano State due to the economic activities in the LGA. It also has more individuals from different states in Nigeria than any of the other LGA's in the state. It has an estimated population of 221,844 inhabitants. (National Bureau of Statistics, 2019b). The accessible population from which the research sample needs to be drawn should be a representation of the target population so that the research findings can applied to similar contexts across the target population. Therefore, Tarauni represents a good choice for the study. However, it is not the entire population of Tarauni that is the focus of the study, rather it is the female students in JSS classes. Data from Kano State Secondary School Management Board (KSSSMB) regarding the population of female students in JSS classes in Tarauni reports an estimate of 5,127. From this population, the research sample was drawn.

Qualitative researchers use several sampling techniques to select research participants. The most common techniques are convenience, snowball, purposive, key informant and theoretical sampling

(Gill, 2020). This study employed convenience, purposive and key informant sampling techniques. The convenience sampling technique involves the researcher selecting from the part of the population close at hand and available for the research (Farrugia, 2019). It is also known as grab sampling, which is economical (Farrugia, 2019), hence, it was used to select the secondary schools from which participants were selected. The study did not aim at making a broad generalisation of its findings to a theoretical population, but rather to gain deeper insights into the situation from a new area so that the conceptualised idea could be used or further explored by similar cases; hence, three schools were selected for the study.

This study agrees that the way the schools were sampled could affect the research findings in several ways; for example, responses gathered from a female-only school might differ from those from a mixed school due to the influence of opposite-sex interaction. Responses gathered from a Catholic school may differ from those gathered from an Islamic school due to the influence of religion. Similarly, responses gathered from a girls-only school may differ from those from a mixed school due to the influence of opposite gender interaction. The effect of school types on the responses could be limitless; as such, the most significant effect was considered. The most significant effect that this study is concerned about is the effect of the socioeconomic status of the different schools.

Students in low socioeconomic class schools may not have easy access to smartphones, the internet, or steady electricity to enable regular and adequate interaction with the PET application. This may affect their responses to the interview, hence, to control for the effect of the different types of schools on the responses, data were collected from only middle to high socioeconomic schools. Schools within this category were randomly selected in Tarauni LGA in Kano state. There are a total of 19 secondary schools in Taurani LGA of which 8 stand out to be of middle to high socioeconomic class. A total of 3 schools were randomly selected from the 8 schools. However, the geographical map of Kano state was used to guide the selection of the schools to ensure a heterogeneous set of participants. The researcher ensured that the schools were physically far apart, to ensure a homogenous set of students. Gill, (2020) explains that sampling participants from the same physical location could be influenced by similar characteristics, such as parental occupation, religion and financial or social status.

The purposive sampling technique involves identifying and selecting participants with the specifics required by the study (Berndt, 2020). The inclusion criteria for participants is that they are in junior secondary classes hence, not just any students in the school were needed. Therefore, purposive sampling was employed to select 15 female students for the study, five junior secondary female students in each school. The study further needed secondary school teachers who taught these students basic STEM subjects; therefore, not just any teacher in the school was a candidate for the study, hence, purposive sampling was used to select five teachers teaching junior secondary school female students in the three schools.

Key informant sampling is similar to purposive sampling. The key informant sampling technique involves selecting participants according to their skills, knowledge and expertise in the field of study or position in society (Gill, 2020). The advantage of this technique was that it allowed the researcher to select information-rich STEM professionals who could provide deeper and unbiased information, ensuring the study's quality (Abdullahi & Chimbo, 2023). Five STEM professionals from various STEM institutions were chosen using key informant sampling. They were professions that the researcher knew. Details of their profile is provided in Chapter 6 and 7 of this study.

The justification for the adequacy of the total sample size (n=25 for framework development and n=32 for PET tool evaluation) used in this study is based on the literature. Marshall et al., (2013) examined 81 publications from leading information system journals and recommended three criteria for determining the adequacy of sample size in qualitative research. The recommendations are: (1) Sample size must be based on suggestions from qualitative methodologists. (2) Sample size must tally with that of prior research in the same field with a similar research problem and methodology (Abdullahi & Chimbo, 2023). (3) Data analysis must demonstrate that data saturation has been reached. In this study, the sample size was based on references from qualitative research methodologists (Shenton, 2004; Bretz, 2008; Holbrook et al., 2007; Malhotra, 2010). For instance, Morse (2000),recommends six to ten interviewees for qualitative research; Denzin and Lincoln (1994), recommend six interviewees; and Creswell (2007) recommends three to five interviewees. Prior studies in information systems similar to this study have used similar sample sizes. For instance, in Angkananon et al. (2013), three experts validated the framework they had designed to enhance technology interaction; Aagaard (2015), used six teachers and fourteen students to investigate the distractions caused by educational technologies in the classroom; and Tshuma

(2018), used nine interviewees to investigate the use of educational technologies in a university; thus, justifying the adequacy of the sample size used in this study.

5.7 DATA ANALYSIS

This section explains how the data was analysed and the measures taken to ensure the validity and reliability of the findings.

5.7.1 Content Analysis Technique

The huge amount of interview data collected was systematically coded and classified using content analysis techniques to identify significant patterns and build logical conclusions (Abdullahi & Chimbo, 2023). According to Lester et al. (2020), content analysis is a method of systematic coding and categorisation of large amounts of textual, visual or auditory data to determine trends, frequency, relationship and discourse of communication. Figure 5.4 illustrates the steps proposed by Lester et al. (2020), followed to analyse the data in this study.

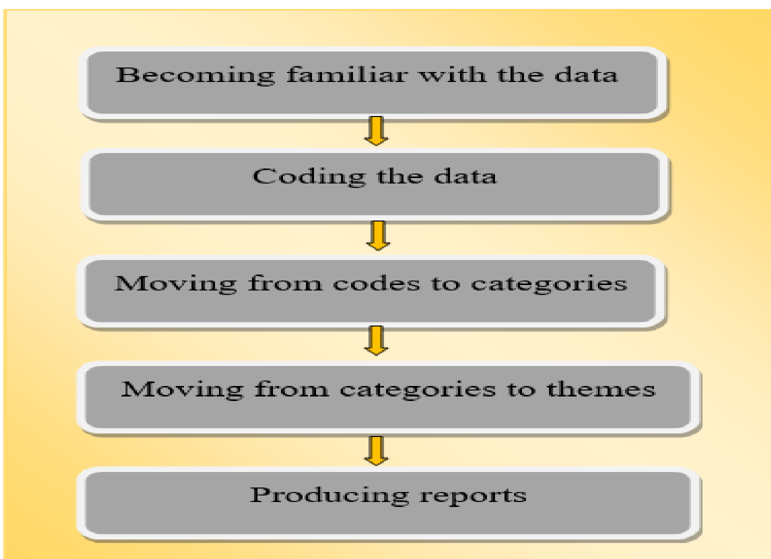

Figure 5. 4: Content analysis steps adapted from Lester et al. (2020)**.**

1. *Becoming familiar with the data.* The researcher spent a considerable amount of time familiarising herself with the data by transcribing the data verbatim into *Microsoft Word* documents and repeatedly reading the transcripts. This step allowed for an initial understanding of the data, which is essential for a more detailed analysis. The researcher made notes of any emergent thoughts during this stage, which helped with the data analysis. *Atlas.ti* and *Microsoft Word* were the main software application tools that facilitated data analysis in this study. The transcribed

interview data for each interview participant was saved in a *Microsoft Word* document and then uploaded to *Atlas.ti* software as single documents.

2. C*oding the data.* The reason for coding is to reduce the size and complexity of the initial transcripts while retaining the contextual meaning of the original data (Abdullahi & Chimbo, 2023). The transcripts were thoroughly and repeatedly read, and then the relevant words and sentences representing a common idea were shortened and labelled with shorter phrases. These labels are the building blocks of the analysis. Each interview transcript was fully coded before moving onto the next interview transcript. According to Stemler (2000), the generated codes must be exhaustive and exclusive. Exhaustive means they must capture all sentences and expressions that are contextually the same. This was carefully done during coding, although the researcher took care that the codes generated were not too broad to prevent further grouping into categories in the next stage. Codes must also be mutually exclusive in that sentences and expressions under one code group are not in another code group as well. This was carefully done when coding. Chapter 6 shows and explains the codes generated.

3. Moving from codes to categories. The researcher and the data analyst separately reviewed the codes and come up with a separate list that grouped the codes into categories. The two lists were then compared to come up with a consolidated set of categories that were of contextual meaning to the study.

4. Moving from categories to themes. Themes can either be generated through an emergent or a priori approach. The emergent approach means the themes are generated from the data, while the a priori approach means the themes are established before the analysis based on a theoretical or conceptual framework. In this study, the development of the theme was guided by the components of the conceptual framework developed in Chapter 4 of the study.

5. Producing reports: In this stage, the researcher came up with an argument to respond to the research question of the study. The report was presented in Chapter 6 of the study.

5.7.2 Validity and Reliability of the Study

The validity and reliability of research are two essential factors that a qualitative researcher should be concerned about while designing, analysing and concluding findings. These measures are a part of what convinces the reader that the findings are worth paying attention to (Bengtsson, 2016; Haven & Grootel, 2019).

Validity is the extent to which the research delivers a true account of the participants' opinions (Haven & Grootel, 2019). Reliability is the extent to which research consistently produces the same results when conducted in the same situation multiple times (Haven & Grootel, 2019). The next section expands on the different reliability and validity indicators employed in the study.

5.7.1.1 Validity Indicators

Three indicators are associated with validity in qualitative research: confirmability, transferability and credibility. A brief description of these indicators and how they were established in the study is given below.

1. Credibility

Credibility refers to confidence in the data. It is the most important validity measure that research must meet (Bengtsson, 2016). Credibility essentially asks the researcher to demonstrate that the research findings are plausible and trustworthy (Stenfors et al., 2020). The study used the two most accepted and widely used techniques for establishing credibility in qualitative research, namely triangulation and member-checking (Bengtsson, 2016; Haven & Grootel, 2019; Stenfors et al., 2020). Triangulation involves using various methods, data sources or theories to ensure true information is derived. Member-checking involves sharing the collected data, the interpretations and the conclusions with the research participants to clarify if these are a true representation of their views.

Triangulation of sources was established in this study by recruiting three different categories of participants: students, secondary school teachers and STEM professionals in different industries. These participants have different levels of understanding and experience of the phenomenon under study. It follows that they provided multiple perspectives on the phenomenon. The triangulation of methods was established by following DSR as the research strategy. This ensured that the framework was redesigned multiple times before a final product was presented.

To establish member-checking, for every cycle of the DSR methodology completed, the final product was presented to the students, then the teachers, and lastly, the STEM experts to confirm if they resonated with the information in the previous version of the framework. All these steps established the credibility of the research.

2. Confirmability

Confirmability is the extent to which research findings can be verified (Haven & Grootel, 2019). This study ensured that the findings were based on participants' narratives and not the opinions of the inquirer. The data collection, data coding, data categorisation, theme development, and other specific details involved in data interpretation were carefully documented to enable investigation of the findings by other researchers. According to Johnson et al., (2020) and Stenfors et al., (2020), confirmation of the findings by other researchers increases the confirmability of the research.

3. Transferability

Transferability is the degree to which findings can be replicated in other, similar contexts and can be established by providing readers with evidence that the research findings could apply to similar situations, times and populations (Haven & Grootel, 2019; Johnson et al., 2020). A detailed explanation of the context in which the research was conducted and how this shaped the findings was provided to establish transferability in this study and to enable other researchers to judge the applicability of the findings to other settings.

5.7.1.2 Reliability Indicators in Research

Reliability in qualitative research does not refer to the extent to which the processes and results are replicable. Instead, because there is the perception that reality is constantly changing and thus, replicating findings might be challenging and epistemologically counter-intuitive, reliability in qualitative research involves keeping detailed documentation of evolving research conditions and research design decisions to confirm the trustworthiness of the research (Bengtsson, 2016; Stenfors et al., 2020). Hence, the indicator used to establish reliability in this study is dependability.

1. Dependability

Dependability is the stability of data over time and under different conditions (Kyngäs et al., 2020; Rose & Johnson, 2020). Because this study research was conducted in the participants' natural settings, it was expected that conditions would vary. Hence, the researcher accounted for changes in the conditions around the participants during the study as well as the consequent changes in research design and data collection. The researcher kept detailed and rich documentation on all design decisions, data collection procedures, analyses and interpretations to enable other collaborators or independent researchers performing similar studies to produce comparable results if using the same research design and methods (Elo et al., 2014).

5.8 ETHICAL CONSIDERATIONS

Before collecting data for the study, the researcher obtained approval from the University of South Africa (UNISA) Research Ethics Committee, which emphasises the fundamental principles expected of any research involving human subjects to protect the rights and safety of research participants (See Appendix G). These ethical fundamentals were taken into consideration during this study. The study complied with the following themes under the committee's policies before ethical clearance was approved:

1. *Informed Consent:* Informed consent is an ethical requirement for human research studies that ensures the purpose of the study and the nature of participants' involvement in the study is explained to participants. In this study, participants were informed about the purpose, potential benefit and effect of publishing the findings from the study. They were also informed that their participation was voluntary and that they could withdraw at any time during the data collection process (See Appendix A). Each potential participant then signed an informed consent form to indicate their understanding of their role in the study and to consent to participate in the study (See Appendix B). Furthermore, because the study involved individuals between 11 and 18 years of age, their parents were informed about the study, and they gave consent for their children to participate in the study (See Appendix C).

2. *Beneficence*: Beneficence is an ethical requirement that ensures a study would not cause any harm to its participants. The participants in this study were informed that involvement in the study would cause them no harm. Their involvement would only be through providing open-ended answers during the interview and focus group sessions. They were allowed to not respond to any question if they were not comfortable answering it. They were also assured that their answers would not affect their marks in any of their subjects in school.

3. *Confidentiality:* The ethics standard emphasised the confidentiality of the participants. Participants' names must not be recorded anywhere, and no one should be able to connect them to

their responses. The confidentiality of participants was protected in the data collection process as the identities of the participants were not disclosed. The researcher used pseudonyms for the participants.

4. *Formal permission:* After rigorous scrutiny of the study's research ethics application form, the committee granted formal approval for data to be collected.

5.9 SUMMARY

This chapter discussed the study's research philosophy and methods, as well as why the philosophy and methods were chosen. Specifically, constructivism was the study's ontological stance because the participants, like all social beings, were from different backgrounds, so their experiences would be unique. This reason led to the selection of interpretivism as the epistemological stance of the study because the dynamics of social beings cannot be understood using techniques like those used for understanding physical phenomena. The study employed DSR as the research strategy because it deals with framework design and implementation.

Chapter 5 further discussed the participant sampling technique, data gathering and analysis techniques. These factors measure the quality, authenticity and trustworthiness of research work. Lastly, the ethical considerations of the study were considered. This chapter enabled the assessment of the validity and dependability of the research by understanding what and how procedures were undertaken. The next chapter discusses the results of the data analysis.

CHAPTER 6: DEVELOPMENT OF THE PERSUASIVE EDUCATIONAL TECHNOLOGY FOR STEM FRAMEWORK

6.1 INTRODUCTION

Chapter 4 conceptualised the PET4STEM framework based on the literature reviewed in Chapters 2 and 3. As explained in Chapter 4, it was relevant for the final PET4STEM framework to identify (i) the factors that influence female students' enrolment into STEM disciplines, (ii) the persuasive strategies to which female students are more susceptible, (iii) the teaching and learning approaches that can accommodate the persuasive strategies and are suited to teaching STEM subjects, and (iv) the technologies that can accommodate the teaching strategies for effective delivery of the instructional contents. These four components guided the development of the interview and focus group session that informed the PET4STEM framework. The purpose of this chapter is to discuss the development of the PET4STEM framework.

The researcher conducted interviews with students, STEM teachers and STEM experts to gather more specific information to inform each component of the PET4STEM framework. The framework provides specific design considerations that would equip PT designers with information to change junior secondary school female students' view of STEM subjects and consequently enrol in STEM pathways.

The PET4STEM framework underwent four design phases, figure 6.1 illustrates the phases. The first phase was based on an interview with students, where questions regarding each component of the framework were posed. Section 6.2 presents the findings from the interview with the students and the development of the initial PET4STEM framework. The second phase was based on the interview with STEM teachers, during which teachers were asked if they agreed with the young women responses and if they wanted anything to be added or removed from the framework. The reports from the teachers were used to develop the PET4STEM intermediate framework, which is presented in Section 6.3. The third phase was based on the interview with STEM experts, whereby they reviewed the components and contents of the intermediate PET4STEM framework and provided suggestions for the development of the penultimate PET4STEM framework. This is presented in Section 6.4. Lastly, a focus group session was held with the students, during which they reviewed the penultimate framework, after which the final PET4STEM framework was developed, as presented in Section 6.5.

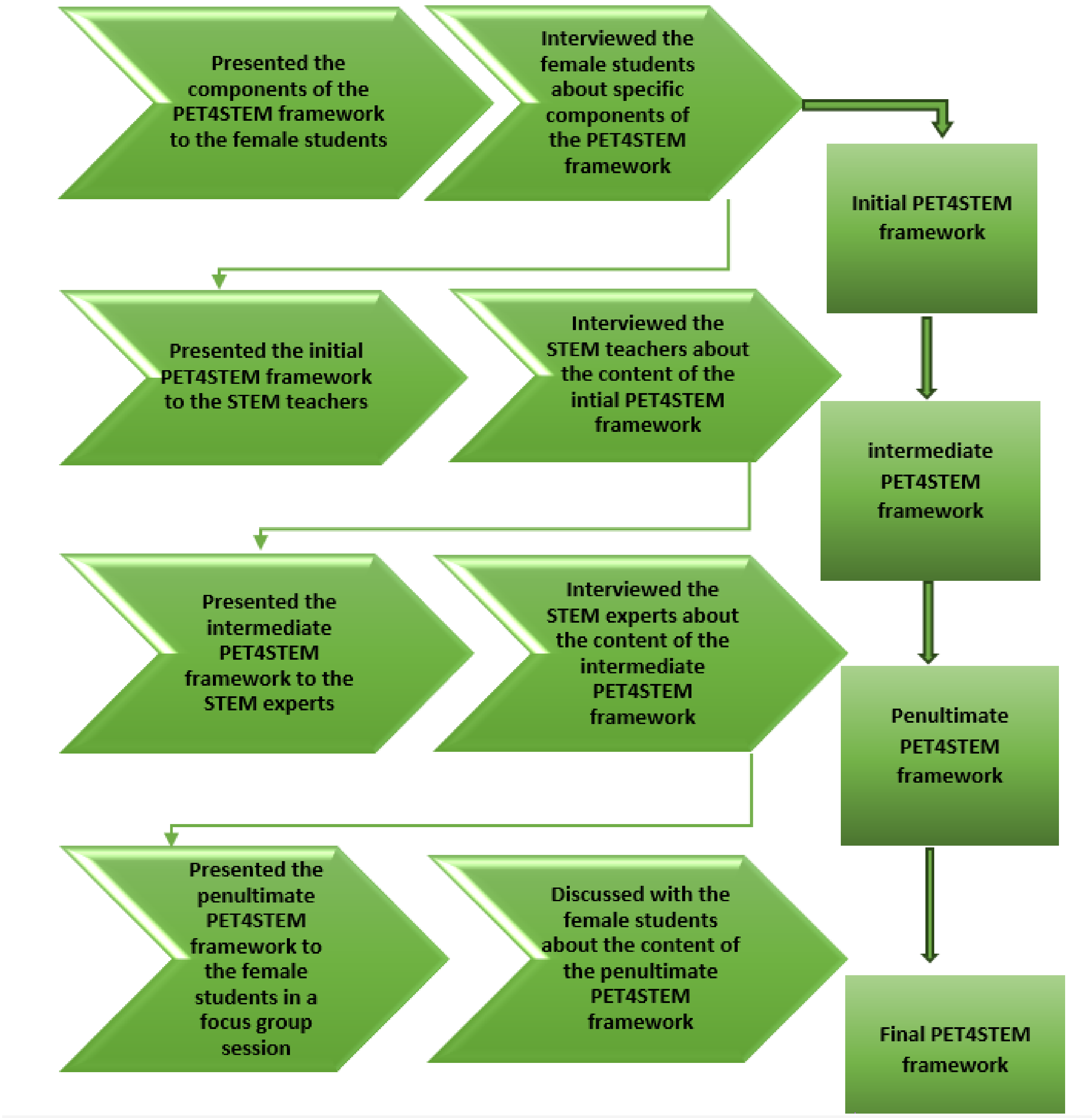

Figure 6. 1 The PET4STEM framework development phases

6.2 FINDINGS FROM THE INTERVIEW WITH STUDENTS AND DEVELOPMENT OF THE PET4STEM INITIAL FRAMEWORK

The interview with the students was divided into four sections. Each section represented one component of the PET4STEM framework as shown in Table 6.1. Section A aimed to ascertain the factors influencing their enrolment in STEM. Section B was dedicated to finding the persuasive strategies to which they are more susceptible. Section C determined the teaching and learning practices that would convince the students to engage more with STEM subjects in class, and lastly, Section C was dedicated to identifying technologies in which the participants would want the persuasive system to be designed.

Table 6. 1: Interview Themes.

Section A. Influencers of STEM enrolment
Section B. Strategies for persuasion
Section C. Engaging teaching and learning approaches
Section D. Technologies for persuasive systems

The responses to the interview questions were transcribed into a *Microsoft Word* document and transferred into *Atlas.ti 22* software. Codes were then assigned to their different responses using the quotation functionality in the tool. Similar codes were grouped into categories, which, in turn, were grouped into themes based on the four components of the conceptual framework listed in Section 6.1. Tables are used for illustration as the findings are discussed. The next section presents the students' profiles.

6.2.1 Student Profiles

Fifteen female students were purposively selected for the interview. The students were all junior secondary school (JSS) students selected from three different schools, with five students from each school. The demographics of the students are shown in Table 6.2. For confidentiality purposes, the students are represented as STUDENT-1, STUDENT-2, STUDENT-3 and so on, and their schools are represented as SCH-A, SCH-B and SCH-C.

Table 6. 2: Demographics of the Students

Interviewee	**School**	**Class**	**Age**	**Choice of profession**
STUDENT-1	SCH-A	JSSII	14	Law
STUDENT-2	SCH-A	JSSII	13	Medicine
STUDENT-3	SCH-A	JSS1	15	TV broadcasting
STUDENT-4	SCH-A	JSSIII	15	Teaching
STUDENT-5	SCH-A	JSSIII	18	Catering
STUDENT-6	SCH-B	JSSI	12	Social work

STUDENT-7	SCH-B	JSSII	16	Medicine
STUDENT-8	SCH-B	JSSII	14	Medicine
STUDENT-9	SCH-B	JSSI	14	Journalism
STUDENT-10	SCH-B	JSSIII	16	Fashion designing
STUDENT-11	SCH-C	JSSI	12	Medicine
STUDENT-12	SCH-C	JSSIII	16	Lab technology
STUDENT-13	SCH-C	JSSIII	16	Law
STUDENT-14	SCH-C	JSSII	14	Banking
STUDENT-15	SCH-C	JSSI	11	Journalism

The students' ages ranged between eleven and eighteen years. Ten students said they wanted professions in non-STEM fields, while five indicated a STEM career. Four of the five who desired a career in STEM aspired to become doctors, and the remaining student wished to be a lab technician. None of the students indicated a profession in engineering or technology. The first insight from this profile was the obvious predilection for non-STEM professions over STEM professions. Second, among those who chose a STEM profession, there was a preference for one profession in the STEM field (medicine) over all others. The choice of profession indicated by these students is consistent with the enrolment rates found in the literature, as reviewed in Chapter 2 (Section 2.4), where females leaned towards health sciences rather than technology and engineering (Babalola et al., 2023). The upcoming subsections report and discuss the findings from the interview and conversations with the students and also attempt to explain this observed profile.

6.2.2 Factors Influencing Students' Enrolment in STEM

The researcher sought not to influence the students' thoughts as they answered the questions; therefore, after asking basic demographic questions, the students were asked general, relevant questions about school, family and themselves, followed by questions about the factors that influenced their choice of profession, and their responses were grouped into social, cultural, family and individual factors.

6.2.2.1 School Factors Influencing Students' Enrolment in STEM

From existing literature, the school factors identified included teachers engaging differently with male and female students, the absence of female STEM teachers, and weak government policies that do not encourage female participation in STEM fields. When the students were probed to find out whether school-related issues influenced their professional choice, their responses indicated that their teachers were supportive of whatever careers they aspired to and that they never felt their teachers gave boys more attention or engaged more with boys in any subject. Rather, the issue raised by those who chose non-STEM professions was that STEM subjects were not taught well enough for them to understand and develop an interest. As indicated by one student: "*Get more well-learned teachers that can explain further and make the subjects very interesting and fun for female students"* (SCHC-Student 13). They reported that if they had teachers who taught STEM subjects well, they might have picked an interest in STEM pathways.

Of the ten students who chose non-STEM professions, eight also reported how the absence of female STEM teachers demotivated them from choosing STEM paths. One student said:

> *I have never seen a female engineering teacher, it's only men. So, whenever they come to the class to teach such subjects you find most of the boys saying they want to be mechanical engineers, electrical engineers, and so on. But you will hardly find that a female wants to be an engineer.* (SCHC-Student 14).

Another said:

> *In school, you can hardly find a woman (female teacher) discussing some of the things regarding STEM. It's like you can find 50 men with only 30 women discussing STEM*. (SCHB-Student 09).

These eight students also disclosed that the very few practical lessons for STEM subjects made the subjects less attractive and affected their interest. One of the responses was:

> *If they can be practicing* (sic) *and doing things in front of us so that we will find it interesting or find it to our liking"* (SCHB-Student 10).

As for the five students who chose a STEM profession, one said what motivated them in school was that: "*our teachers encouraged us that we can be whatever we wanted to be, and this motivated my decision*" an excerpt from (SCHB-Student 07).

Based on their responses, the study understood that school factors hindering the selection of a STEM path include the absence of female STEM teachers, teachers' lack of expertise in explaining STEM concepts, and the lack of practicing what was taught in STEM class while those who indeed chose STEM professions expressed that the school factor that motivated their decision was encouragement from their teachers.

6.2.2.2 Sociocultural Factors That Influence the Students' Enrolment in STEM

Prior studies showed gender role belief as a significant sociocultural factor that drives women's motivation for choosing a profession. The students were probed to determine whether societal norms or expectations influence their professional choices. A student who indicated an interest in non-STEM fields narrated:

> *In my understanding, I think men are supposed to do that job because our culture doesn't want us to do that career* (SCHB-Student 10).

They explained that society believes some roles are fit for one gender and not the other. Even though they did not agree with that, they said that it was a societal belief they had to conform to. As narrated by another:

> *No, women also their mind set is like that. They think they should let men rule over everything and they do whatever society wants them to do (…). And some don't want to do it at all because some of them since from their upbringing the society has already shown them that this is for boys and this is for girls, you should choose this and not go to that*. (SCHB-Student 06).

Those who indicated an interest in STEM professions expressed that society expected women to be helpers and carers, as explained by one student: *"Because the society expects males to be the engineers and some hospitals need females to be a doctor"* (SCHB-Student 07) and thus professions that allowed them to help and care for others would be ideal for them. Doing the opposite will make them seem odd. Another student noted:

> *In my community*[,] *there are few female doctors and nurses so, I want to help. I cannot be doing engineering work when people need doctors in the hospital to help the sick.* (SCHA-Student 2).

Based on the students' responses, it became apparent that the students were adjusting their choice of profession to align with societal norms and expectations. Hence, *societal gender role belief* was identified as the sociocultural factor hindering their choice of STEM professions, whereas those who had chosen STEM professions were enabled by the societal expectation to become helpers and caregivers.

6.2.2.3 Familial Factors Influencing Students' Enrolment in STEM

The literature indicated that the educational attainment of parent(s) and their lines of work are the main familial factors influencing children's professional choices. However, from the interview, the study discovered that their parents' line of work and educational attainment did not influence the students' choices, as elucidated by one student who had chosen a non-STEM profession:

> *No, my parents are not very educated, and they tell me that I can be whatever I want to be. But they will not be comfortable knowing that all my classmates are boys. They will think I will be exposed to some bad things.* (SCHA-Student 01)

Another said:

> *Our religion teaches us how to relate with the opposite sex not preventing us from relating with the opposite sex. But a parent will still not allow their female children go for STEM paths because they will feel their daughters will be exposed to male sex.* (SCHA-Student 03)

None of the students said that their parents' educational level had influenced their choices, and their responses revealed that their parents had different educational levels, ranging from master's and bachelor's degrees to diploma certificates. As regards line of work, only one student believed that parental line of work influenced children's choice of profession; however, when asked if her choice had been influenced by her parents' lines of work, she said no.

Based on the students' narrations, the researcher understood that their parents believed certain careers were meant for men and not women, and they had shared this concern with their daughters. The parents were evidently indifferent about whether or not their children followed their professions or chose other professions. The key point is that they conformed to presumed normal or acceptable choices in their communities, as affirmed by another student:

> *My mum and dad are not lawyers. They are not bothered that I am not taking their path, but they will not want me to be acting like a boy.* (SCHC-Student 15)

The parents' beliefs might have been conditioned by the societal gender role belief, which is not surprising as the literature suggests that societal beliefs are absorbed by the small units of families within society (Carteret, 2010).

None of the parents of students who indicated an interest in STEM professions were in STEM professions and had different levels of education. Three of the students' parents' highest level of education was a master's degree, while one held a bachelor's degree, and another held a diploma certificate. They said their parents were supportive of their professional choices. This buttresses the point that their parents' lines of work and educational attainment did not influence the students' choices. Hence, based on their responses, the family factor that hinders choosing a STEM path is the students' perception that their parents believed some fields were for men only and not for women, whereas, with those who had chosen STEM professions, the family factor that had motivated their decision was encouragement from their parents.

6.2.2.4 Individual Factors That Influence the Students' Enrolment in STEM

The literature identified that the individual factors preventing young women from choosing STEM professions included low self-efficacy in STEM subjects, lack of social belonging in STEM fields, lack of interest, absence of role models, and lack of career-driven goals. When the students were probed to find individual factors that influenced their professional choices, surprisingly (contrary to what other studies have found), only one girl out of those who had indicated an interest in non-STEM professions said that she had low self-efficacy in STEM subjects. Others indicated that if they focused on taking a STEM path, they would have no problem succeeding in STEM classes. The individual factor motivating their choice of profession was the need to help people and improve society. Overwhelmingly, all fifteen students indicated that they were influenced by the motivation to help. Some of the students responded:

> *I want to become a doctor. I want to help my relatives, I want to help people, my gender females.* (sic) (SCHA-Student 04)
>
> *I want to help; I am not going into the profession for money.* (SCHC-Student 15)
>
> *Yes, because my ambition is to really help the society, not financial motivation.* (SCHC-Student 12)
>
> *I love cooking and it entertains me while doing it and people will enjoy it and look happy.* (SCHB-Student 7).

Those who wanted to become doctors indicated that among the STEM professions, medicine was the profession through which they would be able to help others. Those who chose non-STEM professions also indicated that their professional choice would enable them to help people and make their society a better place. They were also asked if they believed that being engineers and computer technologists would not help people. Nine participants acknowledged they would but indicated no interest in such fields and described their lack of interest as natural. One student responded:

> *It's good but I am not really interested in it"* (SCHC-Student 14).

Another said:

> *No, I dislike that kind of work (engineering). I totally don't like them (engineering). Because I don't like it you know, everyone has their own choice.* (SCHA-Student 2)

The remaining six said they were not likely to make much impact on people by being engineers or computer technologists. Some of the responses were:

> *They are useful but in other words what they have done is somehow damaging things easily. Like through social media. Social media has an advantage but nowadays it has become a disadvantage to society*. (SCHA-Student 03)

Another said:

> *Mainly to be making things like phones and other gadgets, will you be able to use those things if you are sick and hungry?* (SCHC-Student 12)

Upon further probing their responses, the researcher realised that their lack of interest was linked to their perception of STEM fields as being things-oriented rather than people-oriented, meaning the STEM field involved interacting with materials rather than humans. As indicated very clearly by SCHA-Student 01, *"Engineering involves repairing old mechanics* (sic)*";* SCHC-Student 06 said,*"You know road constructions and such things are too tedious, they require physical strength"; and* SCHB-Student-09 believed, *"Professions*[,] *where you have to be on the road working with heavy equipment, not talking to anyone, are not my thing"*. The students' knowledge about these fields was limited; they believed that the only work an engineer had was working outdoors with heavy machinery, and according to them, these jobs were most suited to men because of their physical strength. There seems to be inadequate exposure to the different tasks of engineers and technologists. Since they had been conditioned by society to believe that men were meant to do outdoor and physically demanding jobs, they changed their interests to fit the supposed norm in their society. Choosing professions in the engineering and technology fields would be a departure from the societal norm.

Nine of the ten students' who had chosen non-STEM professions spoke about the lack of social belonging as a demotivator for technology and engineering fields. Again, there exists a lack of exposure to things happening outside of their immediate environment. To them, the small number of female students in STEM classes in their school was an indication that this sphere was not for them. The absence of female STEM teachers in school further weakened their sense of belonging in such fields. As explicitly stated in some responses:

> *Working in a place where there are too many men. You know that in a male-dominated workplace*[,] *women will not be comfortable because they don't want to attract the attention of the male sex.* (SCHB-Student 08).
>
> *Oh, when you visit the engineering and technology sections in the university, you just know it's not for me.* (SCHC-Student12)
>
> *The one thing that scares me most is that you don't even see girls there, but in home economics classes you never feel odd.* (SCHA-Student-05)

The study deduced from this interview that the students wanted their thoughts (beliefs) and actions to be consistent, i.e., the young women chose professions they felt resonated with their identity within their milieu. Each of the individual factors identified can be linked to the influence of their societal beliefs. For instance, one could argue that the perception of technology and engineering fields being things-oriented derives from how their society portrays these fields. When the students see construction workers on the road, all they see are men using complicated tools. The media also displays male engineers working with heavy machinery, which impedes the young women's' sense of social belonging. The identified parental factor could also arguably be a societal influence. The school, which is supposed to buffer the effect of these perceptions, also influences the students, which has only exacerbated the societal effect. Female students see few or no female STEM teachers, and the male teachers do not teach the subject in ways that pique their interest.

One could argue that even those who aspired to become doctors were influenced by the need to meet societal expectations, which is part of conforming to societal norms. The young women recognised that society viewed them as more interpersonal and inherently caring, and consequently, they channelled their interests towards professions through which they believed they could help care for people and make people happy. Furthermore, because they were not knowledgeable about the different job roles in engineering and technology, their choice was narrowed to medicine. Within the medical profession, studies find an inclination towards paediatrics and gynaecology subspecialties in which women would treat the more vulnerable of people (women and children) in society, in comparison to male doctors who practised in a broader range of specialities (Garba, 2012; Riaz et al., 2021). Again, the bid to align with being interpersonal and inherently caring might explain the penchant for these specialities. The same argument applies to those who chose non-STEM professions. They would rather save their people from the hands of bad politicians than develop phones, as indicated by one student who wanted to become a journalist.

The in-depth interviews helped uncover the true reasons for the students’ professional choices. If the research had followed the proliferation of literature pointing to self-efficacy, for instance, the researcher would have perceived that the students needed to be motivated to overcome their phobia about STEM subjects. Instead, owing to the questions and conversations, the kind of support this research offers would sustain and reinforce their desire to build a better world while remaining true to their cultural norms and values. Table 6.3 summarises the factors identified from the interview so far.

Table 6. 3: Summary of the Factors Influencing Female Students' Enrolment in STEM Paths Reported by the Students.

Theme	Categories	Codes	
		Barriers	Enablers
Influencers of STEM enrolment	School factors	Absence of female STEM teachers, teachers' lack of expertise, inadequate exposure to practical work in STEM classes.	Teacher encouragement
	Sociocultural factors	Societal gender role belief	Societal expectation to be helpers and caregivers.
	Familial factors	Parental perception of STEM being for males.	Parental encouragement
	Individual factors	STEM being things-oriented, lack of social belonging.	The need to help.

The next section is about the persuasive strategies to which students are more susceptible to inform the persuasion component of the PET4STEM framework.

6.2.3 Persuasive Strategies to Which Students are More Susceptible

After gathering information on the factors influencing their choice of profession, the researcher proceeded to determine the strategies that could be employed to increase the number of female students enrolling in STEM fields for the designers to implement as persuasive design features in PTs. The peculiarity of PTs is their persuasive strategies, and such strategies must be what the users are more responsive to for them to be effective at persuasion.

The students reported a variety of solutions around school, culture, family and personal issues, as indicated by one student who *"…would like a feature where I can see what my mates are doing and be reminded that my decisions are not isolated"* (SCHB-Student 07); and another, who would *"…like to communicate with real-life practitioners, and I like to be competing in quizzes against other groups"* (SCHA-Student 02). The students' responses were coded and then categorised into sets of persuasive strategies. Table 6.4 presents the codes and persuasive strategy categories into which the codes were grouped. The researcher deduced from their responses that their identity did not fit the narrative they had of STEM fields. Hence, there is a need to give them a different view of STEM, which would involve employing strategies to build up their awareness about STEM fields, make them feel connected to STEM fields, and enjoy engaging with STEM subjects.

Table 6. 4: Summary of the Persuasive Strategies to Which Female Students Are Susceptible.

Theme	Categories	Codes
Strategies for persuasion	Competition persuasive strategy	Competing in quizzes, competing in projects.
	Social comparison persuasive strategy	Being aware of what peers are doing, showcasing project works, viewing the work of others, and comparing the progress of peers.
	Collaboration persuasive strategy	Group work, collaboration.
	Reminder persuasive strategy	Prompts to continue to work, reminders to complete tasks, awareness.
	Suggestion persuasive strategy	Prompts on the next steps to take.
	Praise persuasive strategy	Prompts to inform them of their hard work, prompts to tell them they can do better.
	Social facilitation persuasive strategy	Communicating with practitioners, knowing that their decision is not an isolated one.
	Simulation and Rehearsal persuasive strategy	Practising, visualising.

The next section is about the instructional approaches through which the students would prefer to be taught; this was to inform the pedagogical component of the PET4STEM framework.

6.2.4 Instructional Approaches Through Which the Female Students Would Prefer to be Taught.

The students were asked how they preferred to be taught. They showed an attraction to a narrow variety of instructional approaches. Thirteen of them indicate a preference for hands-on learning. As indicated by one student, *"... be practicing* (sic) *and doing things in front of us so that we will* *find it interesting or find it to our liking"* (SCHB-Student 10); another student said, *"... I like learning by doing. All that is taught in class should be taught in the labs…"* (SCHA-Student 05). Only two students said they would prefer to continue learning through conventional methods. Of these two students, one wanted to become a lawyer and the other a journalist. Their intended professions, which mainly involve reading and talking, may explain their preference for the lecture-based learning method. Table 6.5 presents the pedagogies through which the female students would like to be taught.

The obvious desire for a hands-on learning approach implies a significant need to engage more with the subjects. There is a need for pedagogies that foster higher engagement with STEM subjects. Hence, in addition to the pedagogies the students reported, those identified in Chapter 3 of this study were also important to the framework.

Table 6. 5: Presents the Pedagogies Through Which the Female Students Would Like to Be Taught.

Theme	Categories	Codes
Instructional methods	Project-based learning pedagogy	Hands-on learning, practical, projects.
	Conventional learning pedagogy	Lecture-based approach

The next section is about the technologies the students wanted the educational systems to be designed with; this enquiry was pursued to inform the technology component of the PET4STEM framework.

6.2.5 Technologies the Persuasive Systems Could be Designed as

Based on the literature review conducted in Chapter 3, STEM-related PTs were designed as robots, short message services (SMS), games, simulators and learning management systems (LMS). The interview with the students identified four main technologies: collaborative applications, interactive online learning systems, simulation systems and virtual reality systems.

All fifteen students indicated they would like a technology through which they could talk informally, work together, share experiences and receive feedback from other students and mentors. Some of their responses were:

Platforms where we can work together on a single project. Like everyone can chip in their own idea. Just working together. (SCHC-Student 13)

I don't really know how I can learn with a robot. I would prefer to log in and be able to access materials, communicate with other students like me and those above me so that I can ask questions and get answers. (SCH-Student 10)

Of the fifteen, eleven students again expressed interest in *"that* (sic) *kind of applications that model a real-life situation. I never get tired of them"* (SCHB-Student 06). These technologies would involve watching simulated videos, exploring models and rehearsing skills that would allow them to experience things they would not otherwise have, as in the words of another student:

Like my elder brother [,] *in their class they are teaching then* (sic) *acid and base, but because it is dangerous, they can't do* [it] *practically. If I can get an app that will be like real practice, I will truly like it.* (SCHA-Student 01)

Their preference for such technologies might be due to the absence of practical work in school.

Of the eleven students who indicated an interest in simulation technologies, five also indicated an interest in virtual technologies where they can interact with simulated environments. As reported by one of the students:

I personally don't like games but if learning contents can be made visual such that I can manipulate things like in the game world, I would really love that. I have forgotten the name for it again…yes, that's it virtual reality. (SCHA-Student 05)

None of the students mentioned or showed an interest in games and robotics. Table 6.6 presents the information gathered regarding the technologies in which the students wanted a PT to be designed.

Table 6. 6: Summary of Technology That Persuasive Systems Could be Designed as

Theme	**Categories**	**Codes**
Technologies for persuasive systems	Virtual reality technologies	Artificial environments, Computerised manipulation, Virtual reality.
	Simulation technologies	Virtual laboratory, videos, modelling, visualisation.
	Interactive online technologies	Video conferencing, online chat, e-forums, online assessment
	Collaborative applications	Teamwork application, collaborative work.

The initial PET4STEM framework was developed based on the information gathered from the interview with the students and insights from the literature review conducted in Chapters 2 and 3.

6.2.6 PET4STEM Initial Framework

The framework specifically identified the various barriers to junior secondary school female students' enrolment in STEM disciplines for designers to know the specific barriers they should be addressing. None of the existing frameworks identified the challenges or limitations of the desired behaviour (West et al., 2020). Hence, the PET4STEM framework fills this gap. The PET4STEM framework then identified persuasive strategies that can be employed to mitigate each identified barrier. As indicated in Chapter 1, a limitation of the eight-step design framework is that it fails to provide a suggestion for persuasive design principles for designers to employ; thus, designers who follow the eight-step design framework have to rely on other successful PTs for options of such persuasive design principles. The current framework addresses that gap. Moreover, design implementations specific to the barrier were suggested for each of the persuasive strategies identified in the PET4STEM framework. In this way, designers are not burdened with the task of converting persuasive design principles into system features. Again, as indicated in Chapter 1, a limitation of the functional triad framework is that it fails to describe how persuasive design principles can be converted into actual system features for designers to operationalise the persuasive strategies easily in actual PTs. Hence, the PET4STEM framework fills this gap.

It must be noted that the design implementations are specific to female students in Nigeria and STEM subjects, making the framework more context-specific than the PSD framework, which also provides persuasive strategy design implementations but is not focused on any specific domain. The initial PET4STEM framework further provided effective pedagogical approaches that would accommodate the implementation of the identified persuasive strategies suited to delivering STEM learning content to junior secondary school female students. The suggestion of the pedagogical approaches included in the framework is based on extensive research conducted on instructional approaches that can impact students' attitudes toward STEM subjects, as reviewed in Chapter 3. All prior frameworks fail to provide suggestions regarding the domain for which a PT is designed. Furthermore, PT designers were provided with technologies that could be used to deliver the suggested pedagogical approaches appropriate for teaching STEM subjects. Again, none of the prior frameworks address this design aspect, which this framework does. The next subsection discusses the persuasive strategies, pedagogical approaches and technologies for each of the factors, as identified by the female students.

A. ***The absence of female STEM teachers***. To mitigate the effect of the absence of female STEM teachers through a PET, students should be helped to discern that women are indeed involved in teaching STEM. The persuasive strategies that should be employed to achieve this are:

i. Social facilitation persuasive strategy: This strategy involves providing ways of discerning other users performing the desired behaviour (Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers could create a network of available female STEM teachers and female STEM professionals from inside and outside Nigeria who are interested and willing to respond to students’ concerns and answer their questions.

ii. Social role persuasive strategy: This strategy involves designing a persuasive system to mimic people’s social behaviours (Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers could construct virtual female STEM teachers who teach the STEM subjects, answer questions and praise students for good work.

ii. Similarity persuasive strategy: This strategy involves persuading people by imitating them in specific ways (Oinas-Kukkonen & Harjumaa, 2009). This concept is based on the idea that people are more likely to be persuaded by those who are similar to them. In implementing this strategy for this barrier, designers could design virtual female STEM teachers in their PETs and give the avatars Nigerian female names, wear local clothing and speak Nigerian languages.

Pedagogies that can accommodate these strategies are:

i. An inquiry-based learning environment in which different learning scenarios trigger students to ask questions and share ideas with teachers and STEM personnel (Gholam, 2019).

ii. A problem-based learning environment in which students respond to open-ended questions, have to explore different solutions and seek support from teachers and STEM personnel towards searching and arriving at a reasoned solution could also accommodate persuasive strategies (Qamariyah et al., 2021).

Technological platforms that could accommodate these proposed pedagogies for this barrier are learning management systems (LMS) and interactive online learning applications with chat, video conferencing and forum features.

B. Teachers' lack of expertise in teaching STEM subjects. To mitigate the influence of teachers' lack of expertise in teaching STEM subjects through a PET, students should be taught using enhanced instructional methods. the persuasive strategies that should be employed to achieve this are:

i. Reduction persuasive strategy: This strategy involves breaking down complex activities into manageable steps to make the activity attractive (Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers could deconstruct STEM topics into discrete parts. Each part would commence by introducing concepts to students using things they are already familiar with and then allowing students to explain the concepts based on their experiences. Thereafter, the teacher would teach the topic. Designers can also use charts, pictures, audio and videos to aid understanding.

ii. Simulation persuasive strategy: This strategy involves providing real-world experience through a virtual environment(Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers could use simulation models to explain abstract, difficult concepts and allow students to manipulate values to observe how they behave.

iii. Tunelling persuasive strategy: This strategy involves making a persuasive system provide a means for action that brings its users closer to the target behaviour(Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers should show students a model of the outcome of each task before they start with it, and then, with the finished model in hand, guide students through each stage of the task.

iv. Self-monitoring persuasive strategy: This strategy involves providing a means for users to track their performance (Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers should allow students to present what they have learnt periodically. This allows them to reflect on what they have learnt and develop new ideas. Designers should also integrate features that track students' data to determine areas in which they might need assistance and areas in which they might excel.

v. Suggestion persuasive strategy: This strategy involves providing suggestions to individuals while they are engaging in the desired behaviour to make the activity easier (Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers should suggest resource materials that would enhance understanding and provide solutions to different problems.

vi. Collaboration persuasive strategy: This strategy involves enabling users to collaborate in the behaviour change process(Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers should allow the students to work together in groups for those with better understanding to assist others.

vii. Expertise persuasive strategy: This strategy involves providing competent information sampling (Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, when explaining concepts, the information provided and the examples given should be authentic, have variety and be based on current events to enhance understanding.

Pedagogies that can accommodate the proposed strategies for this barrier are:

i. A Project-based learning environment where topics are being taught in parts as mini projects (Qisthi & Arifani, 2020).

Technologies that can accommodate the proposed pedagogies are:

i. Virtual labs where students can conduct virtual projects individually and in groups.

ii. Simulation technologies where students can watch simulated videos.

iii. Interactive online learning applications with conferences for students to upload pictures of their live projects and discuss what they have done. Video presentation features can also be integrated for students to present their works as a group or individually and then discuss what they have learnt.

C. Inadequate exposure to practical work in STEM class. To mitigate the influence of insufficient educational materials for practical work in STEM classes using a PET, students should be involved in practical activities via a persuasive system. The persuasive strategies that should be employed to achieve this are:

i. Rehearsal persuasive strategy: This strategy involves designing a persuasive system to provide a means for rehearsing a behaviour. This might enable people to change their attitudes or behaviour in the real world. In implementing this strategy for this barrier, students could practise methods and techniques taught in metalwork, woodwork, technical drawing, basic science and programming classes repeatedly until they are comfortable with them.

ii. Simulation persuasive strategy: This strategy involves designing a persuasive system to provide real-world experience through a virtual environment(Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers could use simulation models to explain abstract and difficult concepts and allow students to manipulate values to observe how they behave.

A pedagogy that can accommodate the proposed strategy is:

i. A project-based learning environment: Topics and skills could be taught as projects, and the projects should be related to the students' lives.

Technologies that can accommodate this pedagogy are:

ii. Virtual reality technologies with technologies like virtual laboratories could accommodate these strategies, where students can practise basic computer programming.

iii. Simulation technologies where students can watch simulated videos could also support these strategies.

D. Societal beliefs that STEM fields are for men. To mitigate societal beliefs that STEM fields are for men through a PET, awareness should be created that STEM fields are for everyone. The persuasive strategies that should be employed to achieve this are:

i. Social facilitation persuasive strategy: In implementing this strategy for this barrier, designers should provide links to organisations that provide gender-responsive career programs and mentorship programs for secondary school female students to eliminate misconceptions about careers in STEM fields. Designers should also supply information on higher institutions offering STEM scholarship opportunities for female students.

A pedagogy that can accommodate the proposed strategy:

These persuasive strategies do not require a pedagogy for implementation.

Technologies that can accommodate this pedagogy are:

i. Interactive web-based learning applications by which students can follow events, access links, send emails, read blog posts and initiate video calls.

E. Parental beliefs that STEM fields are for men. To mitigate societal beliefs that STEM fields are for men through a PET, awareness should be created that STEM fields are for everyone. The persuasive strategies that should be employed to achieve this are:

i. Third-party endorsement: This strategy involves providing endorsement from respected sources to support the persuasive message being communicated (Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers could provide links or statements from well-known and respected individuals among their audience (like celebrities), countering the misconception that STEM fields are for males only.

A pedagogy that can accommodate the proposed strategy:

These persuasive strategies do not require a pedagogy for implementation.

Technologies that can accommodate this pedagogy are:

i. Interactive web-based learning applications whereby students can follow events, access links, send emails, read blog posts and initiate video calls.

F. The perception that STEM fields are things oriented. To mitigate the effect of the perception that STEM fields are things-oriented through a PET, different STEM learning activities that align with the interests of female students should be developed. Below are the persuasive strategies that should be employed to achieve this:

i. Personalisation persuasive strategies: This strategy involves providing personalised content and services to users(Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers could link the outcome of STEM knowledge and skills to the educational motivation of the students, such as improving people's lives and making people happy. This is one of the main educational motivations of the students who were interviewed, as indicated by one student: *"Yes, because my ambition is to really help* [*the*] *society, not financial motivation"* (SCHC-Student 12).

ii. Tunnelling persuasive strategy: In implementing this strategy for this barrier, designers should share ideas about STEM jobs that relate to students' interests or offer hints that would lead students to connect concepts taught in the classroom to their everyday activities, like cooking, sewing, cleaning, washing and childcare.

iii. Reduction persuasive strategy: In implementing this strategy for this barrier, designers should break down all the job roles in STEM fields and emphasise those that are less physically strenuous and are more indoors. These align with the students' cultural beliefs.

Pedagogies that can accommodate the proposed strategies are:

i. Culturally relevant learning pedagogy can support these strategies: When designing topic content and projects, designers should consider areas and projects that support local environmental and societal causes. Designers should respect the cultural beliefs of female students that women are meant to do less strenuous physical activities; hence, project activities that involve physical labour might demotivate them.

ii. Inquiry-based learning pedagogy whereby students are asked what they want to know about a topic or concept. This creates curiosity in students, leading to questions about what interests them; thus, they drive the content of the learning.

Technologies that can accommodate this pedagogy are:

i. Virtual labs where students can conduct virtual projects individually and in groups can also accommodate these pedagogies.

G. The lack of social belonging. To mitigate the effect of the lack of social belonging through a PET, a female-inclusive learning environment should be created. The persuasive strategies that should be employed to achieve this are:

i. Social facilitation persuasive strategy: In implementing this strategy for this barrier, designers could create a network of female students in STEM disciplines in secondary school, at the undergraduate and postgraduate levels, and practitioners for students to interact with.

ii. Social proof or social learning persuasive strategy: This strategy involves enabling users to learn by viewing the activities of other users (Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy for this barrier, designers should provide continuous information and a means for students to observe and follow projects about STEM women who are making a difference in the environmental, agricultural and security sectors.

iii. Likening persuasive strategy: This strategy involves making a persuasive system appear a certain way that appeals to its users (Cialdini, 2007). In implementing this strategy for this barrier, learning materials should reflect who the students are. Images should resonate with women, colours should be bright (pink, orange, turquoise blue), and the font style should be stylish.

These persuasive strategies do not require a pedagogy for implementation, but rather technologies that can accommodate these strategies:

i. Interactive online learning: Learning management systems, chat applications, forums and conference applications. Table 6.7 presents the initial PET4STEM framework.

Table 6. 7: The Initial PET4STEM Framework.

Factors	Barriers to female students' enrolment in STEM	Educational technology means to mitigate the barriers	Relevant persuasive strategies to employ for mitigating the barriers	Pedagogical approaches to accommodate the persuasive strategies	Technology platform to accommodate the pedagogical approaches
School factors	Absence of female STEM teachers.	Helping the students discern that there are women involved in teaching STEM.	Social facilitation, social role and similarity persuasive strategies.	An inquiry-based learning approach and a problem-based learning approach.	Learning management systems (LMSs) and Interactive online learning applications.
	Teachers' lack of expertise in explaining topics and concepts in STEM subjects.	Teaching students using enhanced teaching practices.	Reduction, tunnelling and expertise persuasive strategies.	Design-based learning approach and project-based learning approach.	Virtual labs, simulation technologies, and online learning applications.
	Inadequate exposure to practical work in STEM classes.	Involving students in simulated practical activities.	Simulation persuasive strategy.	A project-based learning pedagogy	Virtual reality technologies and simulation technologies
Cultural factors	Societal perception about STEM fields being for men.	Creating awareness that STEM fields are for everyone.	Social facilitation persuasive strategies.	Creating awareness that STEM fields are for everyone does not require any specific pedagogy.	Interactive web-based learning applications, and gamified applications.
Familial Factors	Parental perception that STEM fields are for men.	Creating awareness that STEM fields are for everyone.	Third-party endorsement.	Creating awareness that STEM fields are for everyone does not require any specific pedagogy.	Interactive web-based learning applications and gamified applications.
Individual factors	STEM fields being things-oriented.	Designing different STEM learning activities that align with the interests of female students.	Personalisation and tunnelling persuasive strategies.	Culturally relevant learning pedagogy, and context-integration learning pedagogy.	Interactive online learning applications, LMSs and virtual labs.
	Lack of social belonging.	Creating a female inclusive learning environment	Social facilitation and likening persuasive strategies.	These persuasive strategies do not require a pedagogy to create a female inclusive learning environment.	Interactive online learning applications with forums and conference features.

The next phase presents the review of the PET4STEM initial framework by the STEM teachers and the development of the intermediate PET4STEM framework.

6.3 FINDINGS FROM THE INTERVIEW WITH STEM TEACHERS AND DEVELOPMENT OF THE PET4STEM INTERMEDIATE FRAMEWORK

The STEM teachers were briefed on the phase at which the project was and what their participation in this phase entailed. To prevent the teachers' responses from being influenced by the information gathered from the students, the teachers were first asked for their opinions and then the students' responses were shared with them. The interview questions were based on the four interview themes indicated in Table 6.1.

6.3.1 STEM Teachers' Profiles

Five STEM teachers were purposively selected for the interview. The teachers were all from the same secondary schools as the students. Two teachers were from School A, two teachers were from School B, and one was from School C. The demographics of the teachers are shown in Table 6.8. For confidentiality purposes, the teachers are represented as TEACHER-1, TEACHER-2 and so on, and the schools remain as SCHA, SCHB and SCHC.

Table 6. 8: STEM Teacher's Profile

Interviewee	School	Gender	Highest level of education	Age	Classes taught	Years teaching
TEACHER-1	SCH-A	Male	Master's degree	34	JSSI to SSII	8
TEACHER-2	SCH-A	Male	Master's degree	56	JSSI to JSSIII	15
TEACHER-3	SCH-B	Male	Bachelor's degree	25	JSSI to JSSIII	6
TEACHER-4	SCH-B	Male	Diploma in Teachers College	47	JSSI to SSIII	20
TEACHER-5	SCH-C	Male	Bachelor's degree	38	JSSI to SS1I	14

As shown in Table 6.8, two of the teachers held master's degrees, two held bachelor's degrees, and one had a diploma. All the teachers had teaching experience of more than five years. Four of the teachers were well above 30, and one was in their mid-20s. All the teachers were males, and no female teacher was found. The upcoming subsections discuss the findings from each section of the interview with the STEM teachers.

6.3.2 Teachers' Responses to Factors Influencing Students' Enrolment in STEM

The teachers were asked what factors made female students opt for non-STEM instead of STEM fields. The upcoming subsections present their responses.

6.3.2.1 Teachers' Responses to School Factors Influencing Enrolment in STEM

Interestingly, the teachers' responses agreed with those of the students. All five teachers said that the main school factors demotivating female students from opting for STEM fields were teachers' lack of expertise in teaching STEM subjects and inadequate teaching materials, which would have aided students in engaging with the subjects better. As indicated by one teacher:

> *The issue is with the handler (teacher) and issues like communication skills. (…). If students are not fortunate to have a good handler of mathematics subject, they tend to have that kind of phobia or poor interest in mathematics.* (TEACHER 4-SCH-B)

Another teacher also said:

> *School-related issues are first, how buoyant is the school to equip labs for science, and technology activities. Secondly, how good are the teachers to use these to teach the students? Don't get me wrong, there are other school issues like organising extracurricular activities but those are minor issues.* (TEACHER 1-SCH-A)

One would think the teachers would have shied away from admitting the part they played in this issue.

The teachers were asked about the existence of any other school factors; their responses indicated that other school factors, like the absence of effective school counselling programmes and the absence of extracurricular activities, were minor issues that, if resolved, would mean no other issues would be a problem. When probed about whether any school factors motivated those who had opted for STEM paths, they replied, "peer influence", that is, that most students wanted to do what their friends were doing as this reassured them that they were not doing anything considered odd.

The teachers were further probed about whether the lack of teacher expertise and inadequate teaching materials affected both genders, and they responded in the affirmative. They were then asked why such an effect was more pronounced with female students. One of them said it was due to the female students' laziness in not exerting themselves outside of what had been taught in class. His interview excerpt stated:

> *Yes, you hear female students saying I hate maths. So can you imagine? So, one reason is laziness. And that's because they don't think they have any challenges to overcome so they think working hard is a kind of a waste of time. There is unreadiness to task the brain.*(TEACHER-4 SCH-B)

Three teachers felt it was due to a lack of motivation by remarking:

> *To be honest*[,] *our male students are more motivated. They will push and push despite the challenges. The girls aren't… .* (TEACHER-1 SCH-A)

Thestudentss' responses regarding school factors influencing their professional choices were then shared with the teachers. The teachers all agreed with the factors reported by the students. Hence, none of the barriers indicated under school factors were removed from the initial PET4STEM framework, but lack of motivation and laziness were recorded as individual factors, and the teachers were probed about it when the interview reached the part concerning individual factors influencing the female students' choice of STEM professions.

6.3.2.2 Teachers' Responses to Cultural Factors Influencing the Students' Enrolment in STEM

The cultural factors indicated by the teachers were not contrary to what the female students reported. The teachers disclosed that female students were demotivated by the societal gender role belief that some professions were more fit for men while others were for women. When probed about whether any cultural factors motivated those who opted for STEM paths, they responded that there weren't any and that cultural factors only demotivated them. Some of the responses of the teachers were:

> *In most traditions in Nigeria, in fact, all cultures, there is the belief that, oh she is a female she can't be a mechanic; he is a male why is he a cook. And this needs to change.* (TEACHER 2 SCH-A)

> *Although the effect of culture is reducing but it is still a problem in most part of Nigeria. An average northerner, for instance, they will frown at a female being an engineer. Must she dress like a man to earn money? No way! And this is due to ignorance.* (TEACHER 3 SCH-B)

The students' responses regarding cultural factors influencing their professional choices were then shared with the teachers. The teachers all agreed with the factors the students indicated. Hence, the barrier indicated under the cultural factor was not removed from the initial PET4STEM framework.

6.3.2.3 Teachers' Responses on Familial Factors Influencing Students' Enrolment in STEM

The teachers believed familial factors and cultural factors were closely related. All four indicated that the cultural belief about some professions being suited for one gender and not the other has been adopted by families, and this demotivates females from enrolling in STEM professions, as narrated by one teacher:

> *It's hard to differentiate cultural factors and family factors because It's the small units of families that make up the society and it is the families that practice the culture, right? So, the main cultural factor that affects their professional choice is the same as the family factor.* (TEACHER-1 SCH-A).

When probed about familial factors motivating those who chose STEM professions, two of the teachers held that despite family beliefs, if a student came from a family whose members were in a STEM profession, studied STEM disciplines at school or placed a high value on science or education, this could motivate their child to choose a STEM profession:

> *If a female learner comes from a science-oriented background that might affect their STEM enrolment. Another family-related factor is if the family has a love for hard work or education. That would be a privilege for them too.* (TEACHER-4 SCH-B)

Consequently, having a science-oriented family and a love for education was coded as familial factors motivating enrolment in STEM, while family beliefs that STEM is fit for men and not women, were coded as demotivators. The stusents' responses regarding familial factors influencing their professional choices were then shared with the teachers. The teachers all agreed with the factors the students had indicated. Hence, the barrier indicated under the familial factor was not removed from the initial PET4STEM framework; rather, parents' being science-oriented, and valuing education and hard work were added to the list of enablers.

6.3.2.4 Teachers' Responses to Individual Factors Influencing the Students' Enrolment in STEM

The teachers indicated some new factors as individual factors demotivating female students' from choosing STEM professions. These included laziness, lack of ambition, low self-efficacy in STEM subjects, and an inherent preference for working with people instead of objects, although low self-efficacy was mentioned by one teacher. When probed about individual factors motivating those who chose STEM professions to do so, all four teachers reported motivation, high self-efficacy and hard work. Some of the responses of the teachers were:

> *The reason is the maths phobia. Eh, female students as far as I can tell tend to have maths challenge more than males. That's one of the reasons.* (TEACHER 4 SCH-B)
>
> *Females are not driven by money but men are, so that's an individual difference I can see between men and women when it comes to the choice of a profession.* (TEACHER 5 SCH-C)

The students' responses regarding individual factors influencing their professional choice were shared with the teachers, who all agreed with the factors the students had indicated and advised that the list be updated with what they had reported as well. Hence, the barrier indicated under the individual factor in the initial PET4STEM framework was updated to include laziness, lack of ambition, lack of motivation and low self-efficacy. Table 6.9 summarises the factors reported by the teachers.

Table 6. 9: Summary of The Factors Influencing Female Students' Enrolment in STEM, as Reported by the STEM Teachers.

Theme	Categories	Codes	
Influencers of STEM enrolment	School factors	Barriers	Enablers
		Teachers' lack of expertise and inadequate teaching materials.	Peers
	Sociocultural factors	Gender role belief	Societal expectation

	Familial factors	Parents' perception that STEM is for males.	Parents are science-oriented, value education and hard work
	Individual factors	Being lazy, unambitious, having less desire for excessive wealth, low self-efficacy in STEM subjects, and an inherent desire to work with people rather than objects.	Motivation, high self-efficacy, hard work

6.3.3 Teachers' Responses to Persuasive Strategies for the Persuasive Systems

The teachers were asked what strategies could be employed to increase the number of young women enrolling in STEM fields. The teachers provided strategies that were mainly around how to improve STEM teaching and learning in schools. As stressed by one teacher:

> *Features that will make learning fun for them, like one group against another, getting points and displaying winners pictures or group logo and all that.* (TEACHER 3 SCH-B)

The three teachers' responses pointed to integrating gaming features in educational systems, emphasising its significance in teaching STEM to girls, particularly due to their lack of motivation to learn on their own. Three teachers also indicated the need for strategies that allowed the students to collaborate while learning. An interview excerpt from one of them reads: *"Features like quiz competition, features where they can work in groups because they like doing things together, group work motivates them"* (TEACHER 5 SCH-C), explaining that the young women are highly motivated by knowing what other young women like them are doing and by the reassurance that they are doing the same thing as other young women.

The students' responses were then shared with the teachers. The teachers all agreed with the students' responses and those suggested in the PET4STEM framework. They then proposed that game mechanics should be added to the list of persuasive strategies. Additional literature on gamified systems was then reviewed (Cheong et al., 2013; Deterding, 2014; Werbach, 2014; Mele et al., 2020; Zainuddin et al., 2020) to inform designers on game mechanics that are generally accepted and used in the educational context.

According to Georgios et al. (2022), gamified applications are technologies that incorporate game-like elements into non-game systems. In the educational domain, it has been used to improve and make learning more engaging for learners (Deterding et al., 2011; Somayyeh & Batooli., 2011). The most interesting aspect of educational games is that learners do not need to interact with any toys or electronics; it is the learning contents that are being presented using game principles. For instance, making learners compete as they engage with learning content. Offering learners rewards (badges) for positive actions and advancing in stages to complete learning materials are popular strategies employed in gamified educational systems. The motivational attraction of such technologies deepens and prolongs students' engagement with learning materials. The gamified elements identified include points, badges, notifications, levels, leaderboards, quizzes, individual or team missions, events feed, and a progress bar. Figure 6.2 illustrates these elements.

Figure 6. 2: Frequently used mechanics in gamified learning systems (Mele et al., 2020)

Interestingly, some of these game mechanics have been used by designers of persuasive systems as persuasive design strategies. For instance,Orji et al. (2018) used a leaderboard feature to show the position of a student relative to the top ten students in a competition, while Star et al. (2017) used notifications to provide hints to students solving puzzle problems. This implies that gamified elements are not new in persuasive systems. Indeed, Deterding (2014) posits that "gamified systems represent a subset of persuasive systems". Werbach (2014, p.3) also argues that the concept of persuasive systems "includes the use of gameful design". Hence, the gamified elements identified in the literature were added to the list of features of educational systems. Table 6.11

summarises the codes generated from the features reported by the teachers and the persuasive strategy category under which they reside.

Table 6. 10: Summary of The Persuasive Features The Teachers Indicated.

Themes	**Categories**	**Codes**
Persuasive features for persuasive systems	Competition persuasive strategies	Fun features, competition features, game features
	Collaboration persuasive strategies	Online meeting features, teamwork features

6.3.4 Teachers' Response to Pedagogies for Persuasive Systems

The teachers were asked what instructional approaches they believed students would be more receptive to and were best suited to teaching STEM subjects. Two of the teachers said that they had always used the conventional way of teaching, whereby they provided information and responded to students' questions, and they believed this would have been sufficient if there had been hands-on practical work to support it. The other three acknowledged that there are better STEM instructional approaches, and two of these mentioned hands-on teaching and formative assessment as ways to engage students in STEM classes. An excerpt states:

> *The best way to teach STEM subjects are methods that allow students to practicalise what they are thought in class as this will assist them to understand concepts very well and relate it to their everyday affairs. And formative assessment. It is good for assessing students.* (TEACHER 2 SCH-A)

Another teacher reported:

> *I recently attended a training; do you know of an integrated STEM teaching approach? (…). It's a new teaching method that makes STEM subjects relevant to students.* (TEACHER 4 SCH-B)

He explained that it would resolve their lack of motivation to learn on their own.

It should be noted that educators employ different assessment methods to gain insight into how much their students have learnt, some of which are summative, formative, confirmative, normreferenced, criterion-referenced and ipsative assessments (Juwah et al., 2004; Bennett, 2011; Ross et al., 2018). Among these methods, the STEM community has enthusiastically advocated for the formative assessment method (Reynders et al., 2020). Formative assessment is continuously checking students' understanding while they are learning. This assessment method consistently guides the decisions tutors make concerning future instruction and provides feedback to learners to improve their performance. Therefore, the suggestions of TEACHER 2 SCH-B and TEACHER 5 SCH-C were highly appreciated.

The students' responses regarding instructional approaches were then shared with the teachers. The teachers all agreed with the pedagogies the students had indicated and those suggested in the PET4STEM framework. One of the teachers, who stated that formative assessment was a good method for evaluating students, noted that the initial PET4STEM framework already had a self-monitoring strategy incorporating the idea of formative assessment. He then recommended that formative assessment should be added as a pedagogical practice that can accommodate a self-monitoring persuasive strategy. Another teacher suggested that an integrated STEM teaching approach should be added to the list of instructional approaches. Hence, the study reviewed the literature on and integrated the STEM teaching approach.

According to Kelley and Knowles (2016), Nadelson and Seifert (2017) and Thibaut et al. (2018), an integrated STEM teaching approach advocates combining two or more STEM subjects and teaching them as one. The argument for integrated STEM teaching is that real-world problems are not fragmented into disciplines, as taught in schools. Hence, instead of teaching STEM subjects in isolation from others and then hoping students would find a connection when solving real-world problems, it is better to teach STEM subjects together (Roberts & Cantu, 2012). The literature suggests that an integrated STEM learning approach provides opportunities for a "more relevant, less fragmented, and more stimulating learning experience" (Furner & Kumar, 2007, p.186). In a framework developed by Thibaut et al. (2018) to inform researchers and educators about instructional practices for integrated STEM teaching, five teaching practices were presented. These practices include problem-centred learning, inquiry-based learning, design-based learning, collaborative learning and context-integration learning.

Of these instructional practices, problem-based learning, inquiry-based learning and collaborative learning approaches were already included in the initial PET4STEM framework. However, design-based learning and context-integration learning were not included. The literature review informed that design-based learning involves engaging students in the engineering design process, which entails iterative design phases for solving problems. These phases include problem identification, solution definition, solution implementation, solution testing, solution evaluation and solution improvement (Bryan et al., 2015; Wells, 2016). Context-integration learning, on the other hand, involves using contexts from other STEM subjects to make the content of one STEM subject more relevant (Plass et al., 2013). Table 6.12 summarises the pedagogical approaches the teachers indicated.

Table 6. 11: Summary of the Pedagogical Approaches the Teachers Indicated.

Theme	Categories	Codes
Pedagogical approaches for persuasive systems	Conventional teaching approach	Teaching by telling, answering students' questions, and traditional teaching.
	Hands-on learning approach	Hands-on teaching, practical
	An integrated STEM learning approach	An integrated STEM learning approach
	Formative assessment	Formative assessment

6.3.5 Teachers' Responses to Technologies for Persuasive Systems

The teachers were asked what technologies they felt would accommodate the pedagogies and would be accepted and used as a learning system by the female students. Their responses pointed to gamified applications, simulation technology, and collaborative online applications with video conferencing features and chat functionalities. An excerpt reveals:

> *As I said earlier, I think our girls will be attracted to technologies where they can have fun while learning, like competing among one another and earning prizes. They love that a lot in class. I will also suggest where they can work together online, like meetings technologies for face-to-face tutoring so that they feel connected to tutors.* (TEACHER 3 SCH-B)

The students' responses regarding technology for the persuasive system were then shared with the teachers. The teachers all agreed with the technologies suggested in the initial PET4STEM framework. Three of the teachers recommended that game applications should be added to the list of technologies. Hence, gamified systems were added to the list of technologies for which persuasive systems can be designed. Table 6.13 summarises the technologies the teachers indicated.

Table 6. 12: Summary of the Technologies the Teachers Indicated.

Theme	Categories	Codes
Technologies for persuasive systems	Gamified systems	Fun applications, applications where they can compete, educational games.
	Learning management systems.	Technologies to upload and download content and access material asynchronously.
	Simulation technology	Virtual laboratory, videos, modelling and visualisation.
	Collaborative applications	Online meeting applications and teamwork technologies,

From the interview with STEM teachers, more elements were added to the initial PET4STEM framework. The next subsection discusses the persuasive strategies, pedagogical approaches and technologies that were added to the initial PET4STEM framework.

A. ***The absence of female STEM teachers***. No persuasive strategies, pedagogical approaches or technologies were added to mitigate this factor.

B. Teachers' lack of expertise in teaching STEM subjects. The teachers suggested that a design-based learning approach could be added as a pedagogy to accommodate the reduction, simulation, tunnelling, self-monitoring, suggestion collaboration, and expertise persuasive strategies suggested in the initial PET4STEM framework. A design-based learning approach could accommodate these persuasive strategies through its iterative design phases; students could investigate the related and relevant phenomena they are already familiar with in discrete parts by identifying a problem, defining a solution, implementing the solution, and testing and evaluating the solution.

C. Inadequate exposure to practical work in STEM classes. No persuasive strategies, pedagogical approaches or technologies were added to mitigate this factor.

D. Societal beliefs that STEM fields are for men. No persuasive strategies, pedagogical approaches or technologies were added to mitigate this factor.

E. Parental beliefs that STEM fields are for men. No persuasive strategies, pedagogical approaches or technologies were added to mitigate this factor.

F. Laziness. The teachers suggested adding laziness as an individual factor affecting female students' participation in STEM fields**.** The teachers suggested building female students' motivation to persevere to mitigate the effect of laziness. Below are the persuasive strategies that should be employed to achieve this:

i. Tunnelling persuasive strategy: To implement this strategy for this factor, designers should align learning content to activities like photography, fashion design, movie making, home decoration, makeup, cooking and baking. These are the activities that the students enjoy. For instance, designers can link their knowledge and skills in technology to producing cameras for phone photography or link their knowledge and skills in engineering to designing products that make cooking quicker and easier.

ii. Competition persuasive strategy: To implement this strategy for this factor, designers could set quiz competitions and structure quizzes in levels for students to advance from one quiz level to the next.

iii. Reward persuasive strategy: To implement this strategy for this factor, designers can give students rewards like points and badges after winning quizzes to make learning fun and engaging.

Pedagogies that can accommodate the proposed strategies are:

i. Context-integration learning pedagogy could accommodate the tunnelling strategy whereby elements from other subjects or some STEM subjects that interest students are used to make the content of other STEM subjects more relevant.

ii. A collaborative learning environment can accommodate competition and reward persuasive strategies where students are grouped into teams to compete against each other and earn rewards for their team.

Technologies that can accommodate this pedagogy are:

i. LMSs and interactive online learning applications can accommodate context-integration learning.

ii. Gamified educational learning applications can accommodate collaborative learning pedagogy.

G. Lack of Ambition. The teachers suggested adding being unambitious as an individual factor affecting female students' participation in STEM fields**.** To mitigate the effect of laziness, the teachers suggested encouraging female students to set goals for themselves. Listed below are the persuasive strategies that should be employed to achieve this:

i. Social facilitation persuasive strategy: Designers should facilitate students seeing successful women in STEM within Nigeria and around the world to inspire them to become ambitious.

ii. Self-monitoring persuasive strategy: Designers should integrate features tracking students' data to determine areas in which they might need assistance and areas in which they might excel.

Pedagogies that could accommodate the proposed strategies are:

i. The social facilitation persuasive strategy does not require a pedagogy to implement them.

ii. A formative assessment method can support the self-monitoring strategy where periodic feedback on student progress is provided.

Technologies that can accommodate this pedagogy are interactive online learning systems: Learning management systems (LMS), chat applications, forums, and conference applications can accommodate these strategies. Online learning applications and LMSs can accommodate such pedagogies.

H. Low self-efficacy. The teachers suggested adding low self-efficacy as an individual factor affecting female students' participation in STEM fields**.** To mitigate the effect of low self-efficacy they suggested strengthening female students' self-efficacy in STEM. The persuasive strategies that should be employed to achieve this are:

i. Reduction persuasive strategy: Designers can break down complex tasks into moderate tasks since a task that is too difficult might reinforce low self-efficacy, while a task that is too easy would give students the impression that their ability is in doubt.

ii. Social learning persuasive strategies: Designers can introduce students to successful STEM students within Nigeria and from around the world. Students form opinions about their abilities by observing others perform tasks similar to theirs.

iii. Praise persuasive strategy: Designers can send praise as notifications to students for tasks they succeed at and let them know they are capable of succeeding. This boosts their belief in their ability to succeed.

Pedagogies that can accommodate the proposed strategies are:

i. Inquiry-based learning pedagogy asks students what they want to know about a topic or concept. This gives students a sense of autonomy and boosts their self-confidence.

ii. Collaborative learning environments can also support social learning and praise strategies as students can observe their peers succeeding in tasks, and the winning teams are praised for their work.

Technologies that could accommodate this pedagogy are learning management systems and gamified systems. Table 6.13 presents the intermediate PET4STEM framework.

Table 6. 13: The Intermediate PET4STEM Framework

Factors	Barriers to female students' enrolment in STEM	Educational technology means to mitigate barriers	Relevant persuasive strategies to employ for mitigating barriers	Pedagogical approaches to accommodate persuasive strategies	Technology platform to accommodate pedagogical approaches
School factors	Absence of female STEM teachers.	Helping the students discern that there are females involved in teaching STEM.	Social facilitation, social roles and similarity persuasive strategies.	An inquiry-based learning approach and a problem-based learning approach.	Learning management systems (LMSs) and interactive online learning applications.
	Teachers' lack of expertise in explaining topics and concepts in STEM subjects.	Teaching students using enhanced teaching practices.	Reduction, simulation, tunnelling, self-monitoring, suggestion collaboration, and expertise persuasive strategies.	Design-based learning approach and project-based learning approach.	Virtual labs, simulation technologies, and online learning applications.
	Inadequate exposure to practical work in STEM classes.	Involving students in simulated practical activities.	Reduction and simulation persuasive strategies.	A project-based learning pedagogy.	Virtual reality technologies and simulation technologies.
Cultural Factors	Societal perceptions that STEM fields are for men.	Creating awareness that STEM fields are for everyone.	Social facilitation persuasive strategies.	Does not require any specific pedagogy.	Interactive web-based learning applications, and gamified applications.
Familial Factors	Parental perception that STEM fields are for men.	Creating awareness that STEM fields are for everyone.	Third-party endorsement.	Does not require any specific pedagogy.	Interactive web-based learning applications, and gamified applications.
Individual Factors	STEM fields are things-oriented.	Designing different STEM learning activities that align with the interests of female students.	Personalisation, tunnelling, and reduction persuasive strategies.	Culturally relevant learning pedagogy, and context-integration learning pedagogy.	Interactive online learning applications, LMSs and virtual labs.
	Lack of social belonging.	Creating a female-inclusive learning environment.	Social facilitation, social learning and likening persuasive strategies.	No pedagogy is required to create a female-inclusive learning environment.	Interactive online learning applications with forums and conference features.

Individual factors	Laziness	Building female students' motivation to persevere.	Tunnelling, Competition and reward persuasive strategies.	A context integration learning pedagogy can accommodate the tunnelling strategy. A collaborative learning environment can accommodate competition and reward persuasive strategies.	LMSs and interactive online learning applications can accommodate context integration learning. Gamified educational learning applications can accommodate collaborative learning pedagogy.
	Being unambitious	Being unambitious. Encouraging female students to set goals for themselves.	Social facilitation, and a self monitoring persuasive strategy.	Social facilitation does not require any specific pedagogy in this case. A formative assessment method can accommodate a self monitoring persuasive strategy.	Interactive online learning, learning management systems.
	Low self-efficacy	Strengthening female students' self-efficacy in STEM.	Reduction, social learning and praise persuasive strategies.	Inquiry-based learning pedagogy and collaborative learning environments.	Learning management system and gamified systems.

The next phase validates the PET4STEM intermediate framework with the STEM experts and presents the penultimate PET4STEM framework.

6.4 FINDINGS FROM THE INTERVIEW WITH EXPERTS AND THE DEVELOPMENT OF THE PENULTIMATE PET4STEM FRAMEWORK

The interview with the STEM experts was conducted to validate and refine the intermediate PET4STEM framework. These interviews were different as they were not just meant to validate the responses of the students and STEM teachers but also to review the four main components of the framework for relevance. Hence, for each theme indicated in Table 6.1, the experts were asked how relevant the component was in the framework. They were then presented with the students' and STEM teachers' responses and were asked for their opinions regarding the responses and whether they agreed with the suggestion made in the intermediate PET4STEM framework. The next section presents the STEM experts' profiles.

6.4.1 STEM Experts' Profiles

In this study, five experts validated and refined the intermediate PET4STEM framework. According to the literature, utilising at least two experts is acceptable for evaluating an artifact (Shenton, 2004; Bretz, 2008). Holbrook et al. (2007) also pointed out that a range of between two and five experts is ideal for reviewing and validating a framework. The experts used in this study were from different STEM sectors in Nigeria. Soest (2022), suggests that expert selection should be based on their knowledge of the phenomenon being studied; hence, these experts were selected because of their knowledge of female students' education and STEM education in Nigeria. They have published several scholarly articles within the domain of STEM education. Table 6.14 displays the demographics of the experts. For confidentiality purposes, the experts are represented as EXPERT-1, EXPERT-2, EXPERT-3 and so on.

Table 6. 14: STEM Expert Profile

Interviewee	STEM field of expertise	Gender	Highest level of education	Age range	Working field	Years of Experience
EXPT -1	Computer science	Female	Master's Degree	36	University	11
EXPT -2	Civil engineering	Male	Doctoral Degree	58	University	22
EXPT -3	Biochemistry	Male	Doctoral Degree	61	Research Institute	21
EXPT -4	Mathematics	Male	Doctoral Degree	41	University	11
EXPT -5	Electrical engineering	Male	Doctoral Degree	49	Power generation company	9

As shown in Table 6.14, one of the experts holds a master's degree, while four hold doctoral degrees. All the experts had work experience of more than eight years. One of the experts was above sixty years old, two were in their forties, one was above fifty years old, and two were in their late 30s. Four of the experts were males, and one was female. The knowledge and experience of these experts made them suitable to serve as evaluators of the intermediate PET4STEM framework. They could provide relevant information regarding the themes of the interview questions. The upcoming subsections discuss the findings from each section of the interview.

6.4.2 Experts' Review and Validation of the Factors Influencing the Students' Enrolment in STEM

The experts were first asked if it was relevant for the framework to include a component that provided designers with the knowledge of factors that prevent female students from choosing STEM professions. All five of the experts agreed that it was important for designers to be aware of the barriers to female students choosing STEM disciplines. They then reviewed the factors reported in the framework. Except for *low self-efficacy,* which was a factor listed among individual barriers to enrolment in STEM disciplines. All the experts were impressed with the list of factors identified and believed that the list captured the main barriers to female students' enrolment in STEM disciplines in Nigeria. Not all five experts were convinced that low self-efficacy should be included in the list. They indicated that the students lacked the motivation to choose STEM subjects; thus, a lack of motivation should not be interpreted as low self-efficacy. Accordingly, low self-efficacy was marked as a factor to be discussed again with the students during the focus group session, especially since this barrier was mentioned by one teacher and only one of the students indicated she had low self-efficacy in STEM subjects, although she said it was because "*I am not focused on choosing a STEM profession that's probably why I think I will struggle in a STEM class*" (SCHA Student-05).

One of the experts also suggested that "inadequate exposure to practical work in STEM class", which was listed as a barrier under the school factor, should be rephrased "insufficient educational materials for practical work in STEM class". Hence, this barrier was rephrased. Three of the experts again indicated that the students were not particularly lazy but rather lacked the motivation to choose STEM professions. One of the experts stated:

> *I will not say lazy but lack of motivation. They are good at the subjects they are motivated towards.* EXPT-1

Another expert said:

> *This list captures the main challenges. I will not take anyone out. But in this context*[,] *unambitious and lazy are almost saying the same. You should rephrase those.* EXPT-5

These barriers were listed under school factors; hence, the barriers "laziness" and "unambitious" were merged and replaced with the phrase "lack of motivation".

6.4.4 Experts' Review and Validation of the Persuasive Strategies

The experts were then asked if it was relevant to include a component that provides designers with the knowledge of persuasive strategies that the female students would be more susceptible to; all five of the experts agreed that it was an important component. They then reviewed the strategies reported in the framework and were particularly pleased that suggestions on how to implement the strategies were in the framework. They pointed out that more strategies could be added to the framework and that strategies that were already present could be implemented into the framework in several other ways. Three experts suggested the integration of more of Cialdini's (2007) persuasive strategies.

Cialdini (2007) in his book on the psychology of persuasion, Cialdini (2007) presented six influence strategies that have since been used in the marketing domain. Below is an overview of these strategies:

1. Reciprocity: The author believes that people will feel indebted to return a favour whenever they are given a favour. Hence, persuaders should create opportunities whereby their audience would feel indebted to them and adhere to their request.
2. Commitment and consistency: The author assumes that people always want their thoughts and actions to be consistent. Hence, persuaders should lead their audience towards making a small initial commitment, which would subsequently lead to bigger action.
3. Consensus or social proof: This strategy is based on the assumption that people always want their thoughts and actions to conform with those around them and so, would often observe what others are doing. Hence, persuaders should make their audience aware of others performing the same tasks. The social proof persuasive strategy is similar to the social facilitation persuasive strategy of the PSD framework reviewed in Chapter 3, and the social facilitation persuasive strategy is already present in the PET4STEM framework.
4. Authority: This strategy assumes that people are more likely to be submissive to people in authority. Hence, persuaders should use words or proof from such people to persuade.

Authority persuasive strategy, though not previously included in the PET4STEM framework, is a well-known strategy that was also suggested in the PSD framework.

5. Liking: This strategy assumes that people are most likely to be persuaded by people they like. The liking persuasive strategy is already included in the intermediate PET4STEM framework.
6. Scarcity: This strategy assumes that less of something increases demand for it. Hence, the persuader can show the scarcity of something to increase interest in it.

The experts suggested that the scarcity, commitment, authority and social proof strategies should be included in the framework, and they provided ways that these could be contextualised to the study. Their suggestions are presented below.

1. To mitigate the "lack of motivation", a barrier listed under individual factors, the scarcity persuasive strategy was suggested. To implement it, designers should show students the paucity of personnel in technology and engineering fields and how important the skills are to society. The commitment persuasive strategy was also suggested for this barrier. To implement it, designers should allow students to set short-term achievable goals for themselves and note their progress as they work towards their goals.
2. To mitigate the "societal gender role belief", a barrier under cultural factors, the authority persuasive strategy was suggested. To implement this, designers should quote religious leaders who have positive views about women taking STEM pathways.
3. To mitigate the "lack of social belonging", a barrier under individual factors, the social proof persuasive strategies were suggested. To implement this, designers should provide means for students to observe and follow projects about women in STEM making a difference in the environmental, agricultural, and security sectors. This will resonate with the student's desire to make the world a better place.

Strategies already included in the framework were suggested to be implemented in more ways to mitigate the different barriers. The list of the strategies and their implementation is presented below.

1. To mitigate the "societal gender role belief", a barrier under cultural factors, the liking persuasive strategy was suggested. According to the experts, designers can spread

awareness that STEM fields are for everyone by displaying messages from movie stars regularly on the application because the students are likely to be persuaded by people they admire, such as movie stars. It was also suggested that this strategy could be implemented by designing the technology to reflect some of the student's cultures to help them build an emotional connection to the technology.

2. To mitigate the effect of "teachers lack expertise in teaching STEM", the experts indicated that a reduction persuasive strategy could be implemented to enhance teaching by designing PTs to be user-friendly and consume less space and data.
3. To mitigate the effect of "societal gender role beliefs", the verifiability persuasive strategy was suggested. To implement this strategy, the telephone numbers, emails or website URLs of any authorities listed should be provided so that students can reach them to confirm claims.
4. To mitigate the effect of "parental belief that STEM fields are meant for males", a barrier under parental factors, and "low self-efficacy in STEM subjects", a barrier under individual factors, the collaboration persuasive strategy was suggested. To implement this strategy, designers should set activities in which the students and their parents take part. This way, parents would be exposed to their daughters' capabilities, and the students would gain self-confidence.

Strategies not included in the intermediate PET4STEM framework and not part of the prior frameworks were also suggested.

1. Reliability persuasive strategy: According to the expert who suggested this strategy, it involves making the app readily available to users. Hence, designers can implement this by ensuring that updates and maintenance work on the app should not disrupt students' engagement with the app.
2. Role model persuasive strategy: According to the expert who suggested this strategy, it involves having mentors who not only provide information about materials and strategies but also help students set goals and find opportunities for networking with other mentors. This was suggested as a strategy to mitigate the effect of the parental perception that STEM fields were for men.

The researcher highly appreciated the experts' suggestions, which were used to upgrade the intermediate PET4STEM framework. The next subsection presents the findings on the pedagogical approaches to accommodate these strategies.

6.4.3 Experts Review and Validation of the Pedagogical Approaches

The experts were asked if including a component that provides designers with the knowledge of pedagogical approaches that can accommodate the persuasive strategies was relevant in the framework. All five of the experts agreed that it was important. They then reviewed the approaches reported in the framework. They were impressed with the pedagogies suggested in the framework. Some of the comments of the experts were:

> *I am particularly impressed because these instructional approaches can be delivered either asynchronously, or synchronously.* (EXPT-3)
>
> *You have listed a lot of instructional approaches. I can't think of any you haven't included, and these are particularly suited to STEM education.* (EXPT-4)

6.4.5 Experts' Review and Validation of the Technologies

The experts were asked if including a component that provides designers with the knowledge of technologies that could accommodate the pedagogical approaches was necessary. All five experts agreed that it was important for designers to be aware of the technologies. They then reviewed the technologies reported in the framework. Three of the experts said that the technologies indicated in the framework gave a good idea of the technologies the designers could adopt for their PET and added that it would be difficult to make a complete list of all the possible technologies that could accommodate the pedagogical approaches as there are a lot of them. Based on the experts' review, the penultimate PET4STEM framework was developed. Table 6.15 presents the penultimate PET4STEM framework.

Table 6. 15: The Penultimate PET4STEM Framework

Factors	Barriers to female students' enrolment in STEM	Educational technology means to mitigate the barriers	Relevant persuasive strategies to employ for mitigating the barriers	Pedagogical approaches to accommodate the persuasive strategies	Technology platform to accommodate the pedagogical approaches
School factors	Absence of female STEM teachers.	Helping the students discern that there are females involved in teaching STEM.	Social facilitation, social role and similarity persuasive strategies.	An inquiry-based learning approach and a problem-based learning approach.	Learning management systems (LMSs) and Interactive online learning applications.
	Teachers' lack of expertise in explaining topics and concepts in STEM subjects.	Teaching students using enhanced teaching practices.	Reduction, simulation, tunnelling, self-monitoring, suggestion, collaboration, expertise and reliability persuasive strategies.	Design-based learning approach and project-based learning approach.	Virtual labs, simulation technologies and online learning applications.
	Insufficient educational materials for practical work in STEM classes.	Involving students in simulated practical activities.	Rehearsal, simulation persuasive strategy.	A project-based learning pedagogy.	Virtual reality technologies and simulation technologies.
Cultural and familal factors	Societal and family beliefs that STEM fields are for men.	Creating awareness that STEM fields are for everyone.	Authority, verifiability, third party endorsement, likening, collaboration and role model persuasive strategies.	Creating awareness that STEM fields are for everyone does not require any specific pedagogy.	Interactive web-based learning applications and gamified applications.
Individual factors	STEM fields are things-oriented.	Designing different STEM learning activities that align with the interests of female students.	Personalisation, tunnelling, and reduction persuasive strategies.	Culturally relevant learning pedagogy, and context-integration learning pedagogy.	Interactive online learning applications, LMSs and virtual labs.
	Lack of social belonging.	Creating a female-inclusive learning environment.	Social facilitation, social proof and likening persuasive strategies.	These persuasive strategies do not require a pedagogy to create a female-inclusive learning environment.	Interactive online learning applications with forums and conference features.
	Lack of motivation	Building female students' motivation to persevere.	Tunnelling, competition, reward and scarcity persuasive strategies.	Context-integration learning, collaborative learning, and inquiry-based learning environment.	LMSs, interactive online learning, gamified educational learning applications, and simulation technologies.
		Encouraging female students to set goals for themselves and persevere to achieve their goals.	Commitment, social facilitation and self-monitoring	A project-based learning and formative assessment method.	Interactive online learning; LMSs can accommodate such pedagogies and virtual labs.

6.5 REVIEWING THE PENULTIMATE FRAMEWORK WITH THE FEMALE STUDENTS AND THE DEVELOPMENT OF THE FINAL PET4STEM FRAMEWORK

A focus group session was conducted with all 15 female students to confirm if they were pleased with the information provided by the STEM teachers and experts. They expressed eagerness "*to see what our teachers said about us and what the experts recommended*" (SCHB-Student 09). It appeared they felt the low number of females in STEM fields was an issue, and a solution was long awaited. They were informed that whatever they did not agree with in the framework would be noted and reviewed with the teachers and STEM experts.

The students chatted among themselves about the features they liked the most: "*…the fact that we would connect with other females in STEM is great.*" (SCHA Student-04), "*I like that the STEM teachers' avatars would have names like ours and speak our local dialect.*" (SCHB Student-10). They were then asked if they thought anything should be removed or added to the list. They all indicated that nothing should be removed and did not have suggestions of what should be added.

The pedagogical approaches were then written next to the persuasive strategies alongside what they meant and how they could be implemented. Again, there was a lot of excitement about the way the instructions could be delivered. The students were happy to find out about other teaching strategies that could enhance engagement with STEM subjects. They were particularly excited about content integration learning because "*woodwork and metalwork will no longer be boring since our interests from other subjects will be accommodated in these classes*" (SCHA Student-02) and inquiry-based learning where they *"will channel the questions to what we find more interesting and relevant to us rather than what they think is more interesting*" (SCHA Student-05). They were then asked if they thought anything should be removed or added to the list. They all indicated that nothing should be removed and did not have suggestions of what should be added.

The list of technologies to accommodate these pedagogies was then written next to the pedagogical approaches alongside what they meant and how they could be implemented. The students were elated about the listed technologies; the virtual learning applications and chat applications were of particular interest to the students. They made remarks like *"The virtual apps will definitely go a long way, imagine seeing the chemistry behind cooking food"* (SCHA Student-05) and "*Being able to get your concerns heard by someone in the field will be good* *for me"* (SCHB Student -09). They were asked if there was any technology that should be added to the list, and they said no. Tabe 6.16 presents the final PET4STEM framework.

Table 6.16: The Final PET4STEM Framework

Factors	Barriers to female students' enrolment in STEM	Educational technology means to mitigate the barriers	Relevant persuasive strategies to employ for mitigating the barriers	Pedagogical approaches to accommodate the persuasive strategies	Technology platform to accommodate the pedagogical approaches
School factors	Absence of female STEM teachers.	Helping the students discern that there are females involved in teaching STEM.	Social facilitation, social role and similarity persuasive strategies.	An inquiry-based learning approach and a problem-based learning approach.	Learning management systems (LMSs) and interactive online learning applications.
	Teachers' lack of expertise in explaining topics and concepts in STEM subjects.	Teaching students using enhanced teaching practices.	Reduction, tunnelling, self-monitoring, suggestion, collaboration, expertise and reliability persuasive strategies.	Design-based learning approach and project-based learning approach.	Virtual labs, simulation technologies and online learning applications.
	Insufficient educational materials for practical work in STEM classes.	Involving students in simulated practical activities.	Rehearsal and simulation persuasive strategy.	A project-based learning pedagogy	Virtual reality technologies and simulation technologies
Cultural and familial factors	Societal and family beliefs that STEM fields are for men.	Creating awareness that STEM fields are for everyone.	Social facilitation, authority, verifiability, liking, collaboration and role model persuasive strategies.	Creating awareness that STEM fields are for everyone does not require any specific pedagogy.	Interactive web-based learning applications, and gamified applications.
Individual factors	STEM fields are things-oriented.	Designing different STEM learning activities that go with the interests of female students.	Personalisation, tunnelling, and reduction persuasive strategies.	Culturally relevant learning pedagogy, context integration learning pedagogy and inquiry-based learning pedagogy.	Interactive online learning applications, LMSs and virtual labs.
	Lack of social belonging.	Creating a female-inclusive learning environment.	Social facilitation, social proof, liking and tunnelling persuasive strategies.	These persuasive strategies do not require a specific pedagogy to create a female-inclusive learning environment.	Interactive online learning applications with forums and conference features.
	Lack of motivation	Building female students' motivation to persevere.	Tunnelling, competition, reward and scarcity persuasive strategies.	Context-integration learning, collaborative learning and inquiry-based learning environment.	LMSs, interactive online learning, gamified educational learning applications and simulation technologies.
		Encouraging female students to set goals for themselves and persevere to achieve the goals.	Commitment, social facilitation and self-monitoring.	A project-based learning and formative assessment method.	Interactive online learning, LMSs and virtual labs can accommodate such pedagogies.

6.6 SUMMARY

Chapter 6 presented the process of developing the PET4STEM framework, which involved three phases of interviews with female students, STEM teachers, and STEM experts and a focus group session with female students before reaching a final framework.

The first phase was an interview with female students. From the interview with the students, the true reasons for their professional choices were uncovered. It became evident that environmental context influences the identity they assume, the extent to which they engage with a task, and the types of career choices or goals they set for themselves. If the research had adopted the claims from existing literature, the kind of support the research would have offered might not have addressed the problem adequately. However, during the in-depth interview, the researcher realised the students needed to be assured that they could pursue their desire to improve society through STEM fields while remaining true to their cultural norms and values. The information from the interview with the students led to the development of the initial PET4STEM framework.

The second phase involved presenting the initial PET4STEM framework to the STEM teachers for their opinions regarding the elements of the framework. Surprisingly, the teachers agreed with what the students reported. They admitted to issues such as lacking the expertise and resources to teach STEM subjects to female students in ways that would attract them to the subjects. The information gathered from the teachers was used to update the initial PET4STEM framework; subsequently, an intermediate PET4STEM framework was developed.

The third phase involved presenting the intermediate PET4STEM framework to the STEM experts for review. The experts' review revealed that it was unrealistic to develop a framework that is exhaustive of all the barriers, strategies, instructional approaches or technologies that designers could employ. At best, what a framework could offer was a guide giving a designer an idea to build on, because they needed some flexibility to include their imagination into the design. The information gathered from the experts' interview led to the development of the penultimate PET4STEM framework.

The fourth phase involved reviewing the penultimate PET4STEM framework in a focus group session with the female students. The students who were satisfied with the penultimate framework, except for a few adjustments. This led to the development of the final PET4STEM framework. The final PET4STEM framework consists of a component listing the barriers to junior secondary school female students' enrolment in STEM, a persuasion component identifying the persuasive strategies that could be used to mitigate barriers, along with suggestions for their implementation in a PET, a pedagogical component that indicated various instructional approaches suited to STEM and that could accommodate the identified persuasive strategies. Lastly, a technology component identifying technologies the PETs could be designed as.

This framework might not have exhausted all the persuasive strategies, pedagogical approaches or technologies in the literature; however, in practical terms, one PET cannot integrate all of what was suggested in the framework. From a practical standpoint, and what was advised, was that a PET selects some barriers to address and then implements the suggestions from the framework. Second, the framework was limited to a specific context, meaning it was not generic like the existing frameworks. Third, its content was based on information gathered from the audience (female students) for which the PETs would be designed. The next chapter implements the final PET4STEM framework.

CHAPTER 7: IMPLEMENTATION AND EVALUATION OF THE PET4STEM FRAMEWORK

7.1 INTRODUCTION

In the previous chapter, a PET4STEM framework was designed based on the interview and focus group data gathered from junior secondary school female students, STEM teachers and STEM experts. The designed PET4STEM framework contained specific design considerations that would equip PT designers with the requisite information to persuade junior secondary school female students to view STEM subjects differently and, consequently, enrol in STEM pathways. The purpose of this current chapter is to report the implementation and evaluation of the PET4STEM framework.

The researcher is aware that it is difficult to evaluate the innovative PET4STEM framework based solely on its design. Hence, specific software was developed to implement and evaluate the PET4STEM framework. However, due to the limited time remaining for the study, it would produce a poorly designed PET tool if a full-scale PET tool were attempted (Prieto-Rodriguez et al., 2020). Hence, for the implementation and evaluation of the PET4STEM framework, a pilot PET was developed and evaluated. For this pilot implementation and evaluation, the study focused on testing the feasibility of implementing the components of the PET4STEM framework in actual software. It also evaluates the acceptance of the idea of a PET tool among students and STEM personnel, whether they find it safe to use, engaging, and its motivational prospects before subsequent formal implementation by other developers for secondary school female students.

Hence, this chapter discusses the development of a pilot PET tool that allowed junior secondary female students to learn STEM subjects with female STEM personnel present to answer their questions, listen to their concerns and provide guidance. The chapter then reports the engagement of the female students with the pilot PET tool and the personal experiences and reflections of the female STEM personnel who used the tool. The findings from this chapter could provide PT designers with information about the impact of a PET tool developed from the PET4STEM framework.

The rest of the chapter is organised as follows: Section 7.2 presents the rationale for developing a pilot tool instead of a full-scaled tool. Section 7.3 then presents an overview of the pilot PET tool, outlining what the tool was focused on achieving. Section 7.4 captures how the tool was developed, while section 7.5 discusses how the tool functions, including an explanation of the flowchart of the tool. Section 7.6 then discusses the main components of the tool and how they operate for both students and STEM professionals. This is followed by Section 7.7, which discusses the students' experiences with the PET tool. Section 7.8 presents the STEM personnel's reflections on the PET tool. Lastly, Section 7.9 summarises the chapter.

7.2 THE RATIONALE FOR DEVELOPING A PILOT APPLICATION

According to In (2017), a pilot project is a small-scale preliminary project conducted before executing the full-scale project to evaluate the feasibility, duration, cost and adverse events prior to a full-scale project. In this study, a pilot PET tool was developed because there was limited remaining time for the study to develop and evaluate a full-scale PET tool (Prieto-Rodriguez et al., 2020). Developing a full-scale PET tool can take a minimum of one year, and evaluating the impact of the full-scaled PET tool can also take a minimum of one year (Prieto-Rodriguez et al., 2020). This is because to determine whether or not the tool is able to motivate a student to choose a STEM pathway when they reach SSI, the researcher would have to follow the students for at least one year if the student is in JSSIII, two years if the student is in JSSII, and three years if the student is in JSSI.

In addition, the literature reviewed in Chapter 2 revealed that most educational technology interventions aimed at increasing female students' engagement and enrolment in STEM disciplines were short-term interventions (one to 24 hours) (Feng & Tuan, 2005; Matson et al., 2007; Marshall et al., 2010) and mid-term interventions (one to nine weeks) (Summers & Bauman., 2010), which, according to Prieto-Rodriguez et al. (2020), only captures short-term outcomes that are not indicators of long-termed engagement, such as enrolment in STEM disciplines. To wit, short- or medium-term interventions are not realistic ways of assessing whether a student would enrol in a STEM discipline in the future (Prieto-Rodriguez et al., 2020).

In this study, testing the PET tool with the students and STEM personnel lasted for only three weeks, which is a short period for a thorough and realistic evaluation of such an intervention. Hence, this study intended to analyse the students' and STEM personnel's responses about the features of the PET tool to understand their experiences with the PET tool. The researcher used this to imply whether the PET tool developed following the PET4STEM framework had the potential to motivate junior secondary school students to choose STEM pathways if used as an intervention for a longer period.

7.3 AN OVERVIEW OF THE PILOT PET APPLICATION

The previous chapter stated that one PET tool cannot integrate all the suggestions in the PET4STEM framework. The study advised that a designer should select some of the barriers they wanted to address and then implement the suggestions from the framework. The next sub-section discusses the barriers that were chosen as the focus of the pilot PET tool and the persuasive strategies, pedagogical approaches or technologies selected for implementation based on the PET4STEM framework.

7.3.1 The Barriers That Are the Focus of the Pilot PET Application.

For this PET tool, the researcher focused on two barriers. The first was the absence of female STEM teachers, which is a barrier identified under the school factors affecting female students' choice of STEM professions, while the second was societal and parental perceptions that STEM fields were for men, which is a barrier identified under cultural and familial factors affecting female students' choice of STEM professions.

7.3.2 The Persuasive Strategies Chosen to Mitigate the Barriers.

According to the PET4STEM framework, to mitigate the effect of the absence of female STEM teachers through a PET, students should be helped to discern that women were indeed involved in teaching STEM subjects. The persuasive strategies suggested to achieve this goal are the social facilitation persuasive strategy, the social role persuasive strategy and the similarity persuasive strategy. Among these strategies, the social facilitation persuasive strategy was chosen to be implemented in the pilot PET tool. The reason for selecting this strategy rather than the other strategies was that it was easier to implement. This strategy would allow for the pilot tool to be completed within the study's time frame. This strategy involves providing a means for discerning other individuals who are performing the desired behaviour (Oinas-Kukkonen & Harjumaa, 2009). In implementing this strategy, the suggestion was that designers should create a network of available female STEM teachers and female STEM professionals both from within and outside of Nigeria who were interested and willing to respond to the students' concerns and answer their questions.

Following the PET4STEM framework, to mitigate the second barrier that was the focus of the pilot PET, which is societal beliefs that STEM fields are for men, through a PET, awareness should be created that STEM fields are for everyone. The persuasive strategies that should be employed to achieve this are social facilitation, authority, verifiability, likening, collaboration and role model persuasive strategies. Among these, the social facilitation persuasive strategy was again chosen to be implemented in the PET tool. In implementing this strategy for this barrier, the suggestion was that designers should provide links to organisations that provide gender-responsive career and mentorship programs for secondary school female students to eliminate misconceptions about careers in STEM fields. Further, designers should also make information available on higher institutions offering STEM scholarship opportunities for female learners.

7.3.3 The Pedagogical Approaches Chosen to Accommodate the Strategy.

The pedagogical approaches suggested in the PET4STEM framework to accommodate this strategy were inquiry-based learning and problem-based learning environments. The inquiry-based learning approach promotes the use of different learning scenarios that trigger students to ask questions and share ideas with their tutors (Gholam, 2019), while the problem-based learning approach promotes the use of open-ended questions requiring students to explore various solutions and seek support from their tutors towards searching and arriving at reasoned solutions (Qamariyah et al., 2021). These two pedagogies were employed in the PET tool. Specifically, inquiry-based learning activities were created that required students to ask questions and share ideas with the STEM teachers and STEM personnel on the platform. Moreover, the problem-based learning activities required students to explore various solutions and seek support from the STEM teachers and STEM personnel before arriving at solutions.

As regards the second barrier that was the focus of the pilot PET, implementing the social facilitation persuasive strategy for this barrier did not require any specific pedagogical approach because it involved creating links and providing information about these organisations.

7.3.4 The Technology Platform Chosen to Accommodate the Pedagogical Approaches.

The technology platforms suggested in the PET4STEM framework for these pedagogies were learning management systems (LMSs) or interactive online learning applications with chat, multimedia, video conferencing and forum features. The research chose to design PET as an interactive online learning application with chat and multimedia features. The reason for choosing this technology was to enable the students to interact optimally with the STEM teachers and STEM personnel when doing the activities.

As regards the second barrier that was the focus of the pilot PET, the technology suggested is an interactive web-based learning application where students could follow events, access links, send emails, read blog posts and initiate video calls. Hence, in the designed PET tool, features whereby students could read blog posts, follow events about gender-responsive career and mentorship programs, and access links to institutions offering STEM scholarship opportunities for women were integrated.

7.4 TOOLS EMPLOYED TO DEVELOP THE PILOT PET APPLICATION

The pilot PET tool was developed from scratch. The study used the *Laravel* framework to develop the tool. *Laravel* is a web application framework that provides a powerful syntax for developing robust web applications. The researcher utilised *JavaScript* as the scripting programming language and *jQuery* libraries to simplify event handling and manipulation of the *Document Object Mode* (*DOM*) of the application pages. *jQuery* was chosen from other *JavaScript* libraries because it addresses browser compatibility issues more efficiently since the study anticipated that the participants would be accessing the platform using various web browsers and browser versions. The study employed *MySQL* as the relational database management system because it is a powerful and secure data storage system and is thus suitable for this PET tool. Lastly, the study utilised *Pusher WebSocket* as the communication protocol for client-server communication because the PET4STEM tool has real-time web applications such as a chat platform whereby data must be continuously pushed by the backend server to the client end, using a fast and reliable channel.

7.5 HOW THE PILOT PET APPLICATION WORKS

The landing page of the pilot PET tool has separate links for students and STEM personnel to register an account. For those who have already registered, there are separate links for students and STEM personnel to log in. Once logged in, the user is directed to the tool’s dashboard. For students, the dashboard has an icon for each of the four main components: a chat platform, a resource centre, an area for narratives about women in STEM, and a game centre. For STEM personnel, the dashboard has two main components: a chat platform and a resource centre. Students can then choose the component with which they want to interact. Figure 7.1 is a flow diagram illustrating how the application works.

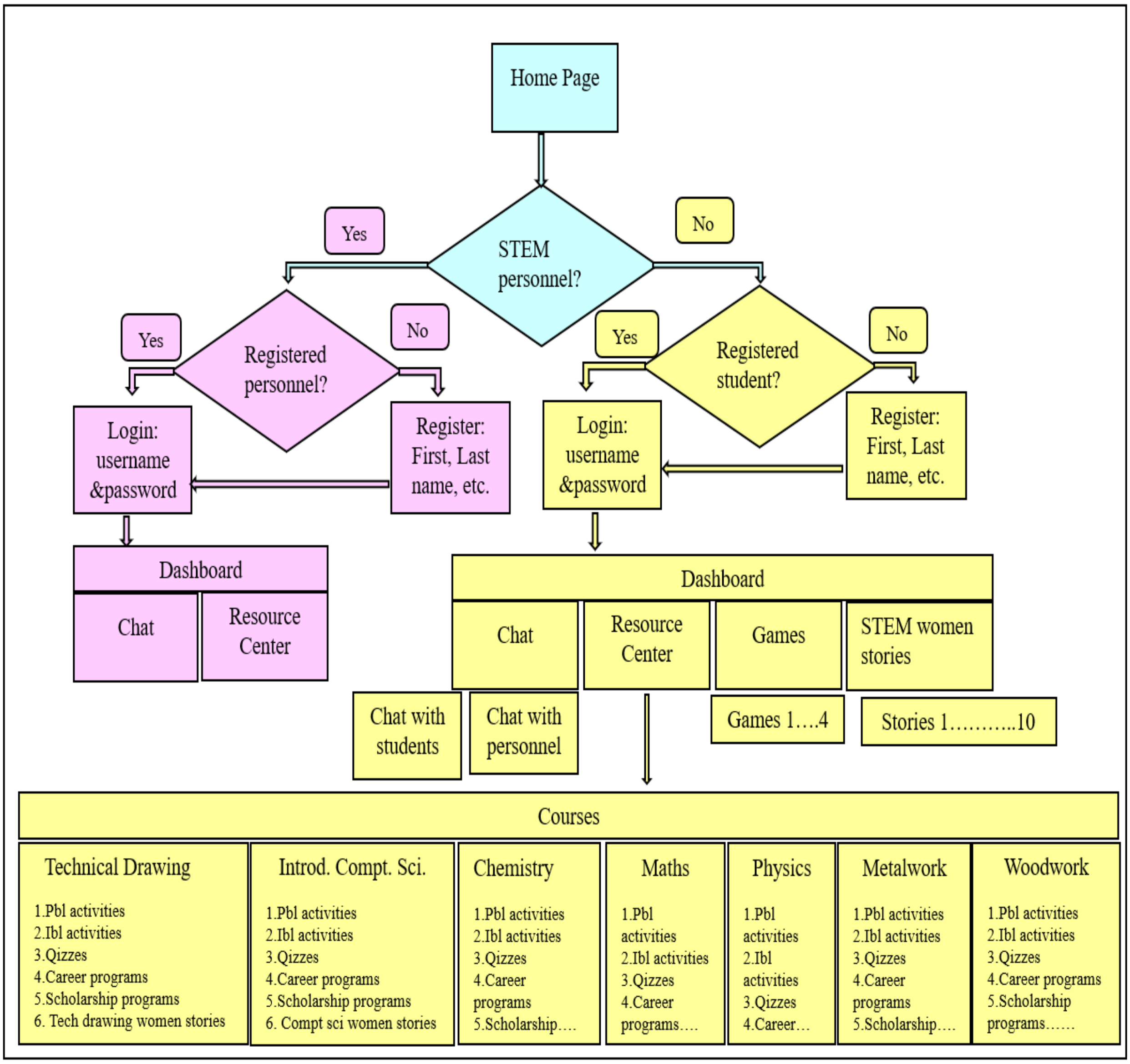

Figure 7. 1: Flow diagram of how the PET application works.

The next subsection discusses the four main components of the platform and their use.

7.6 COMPONENTS OF THE PILOT PET TOOL

As previously mentioned, the pilot PET tool was designed in the form of an interactive web-based tool. Its main targets were to help junior secondary school female students discern that there were indeed women involved in teaching STEM and also to create awareness among the students that STEM fields are for everyone, not just men. As a result, the tool has the following components.

1. A chat platform
2. A resource centre
3. An area for narratives about women in STEM

4. A game centre

1. The chat platform: A chat platform was a suggested feature in the PET4STEM framework, and it was designed specifically to afford communication among the students and between students and STEM personnel while the students engage with project- and inquiry-based learning activities. As a result, there are two chat platforms on the PET4STEM application. There is a chat platform called “chat with students”, where students chat with one another, and there is another one called “chat with STEM personnel”, where students can chat with the female STEM personnel registered on the tool.

In “chat with STEM personnel”, there is a “favourite” feature where students can select their favourite STEM personnel member and chat with them. If they do not have any favourites, they can choose from the list of STEM personnel and chat with anyone. Students come to this chat area when they are working on activities that require them to seek the opinion of STEM personnel. Students must present their ideas through video recordings, voice notes or texts and then wait for feedback from personnel. The students will keep communicating with the personnel until they have both arrived at a solution and then the students can submit the activity. After the student has completed and submitted the activity, they can then post their debates, arguments or suggestions on their status for everyone to view. Figure 7.2 is a screenshot of the chat platform where students can chat with any STEM personnel of their choice.

In the “chat with student” area, students can chat with students from any class. This is to allow students in junior classes to ask questions of those in a higher class. Students are also encouraged to share their debates and arguments with other students before approaching the STEM personnel. Everyone’s chat area has a profile setting where students can choose feminine themes and colours like pink, peach, violet, yellow and turquoise blue for their chat pages. This is intended to make the chat environment appear feminine to the students.

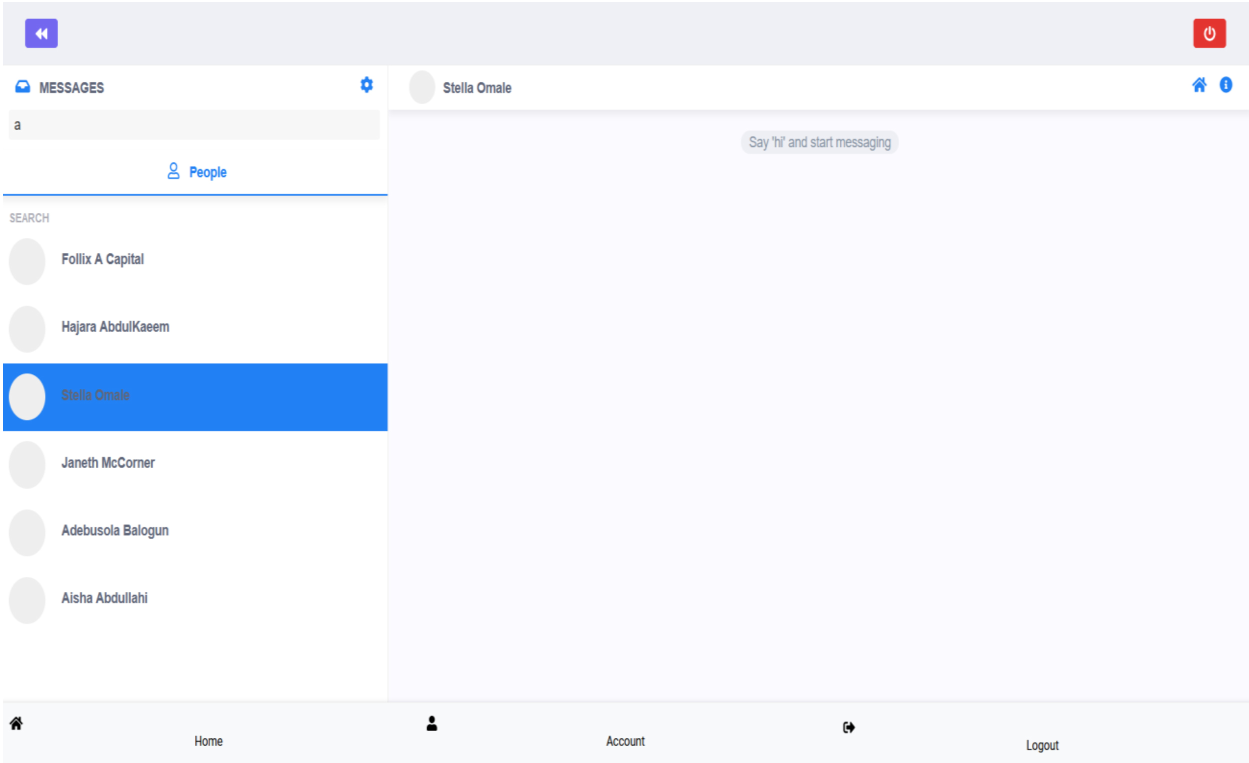

Figure 7. 2: The chat area for chatting with STEM personnel.

2. The resource centre: The resource centre is mainly for the students, but STEM personnel can also view this area. It contains all the subjects on which the PET tool is focused, and the subjects are mathematics, physics, introduction to computer science, metalwork, woodwork, technical drawing and chemistry. Figure 7.3 displays a screenshot of this area.

Figure 7. 3: A screenshot of the list of courses in the PET resource centre.

When a student clicks on a subject, a list of different resources is displayed. For each of these subjects there are:

1. Study materials in which students can access different print, video and audio material about the subject.
2. Different problem-based learning activities
3. Different inquiry-based learning activities.
4. Quizzes ranging from 20 minutes to one hour completion time.
5. A list of higher institutions and bodies offering STEM scholarship opportunities to female students.
6. A list of bodies offering career and mentorship programmes to eliminate misconceptions about women and STEM professions.

7. Narratives about amazing women in the field (The narratives here are specific to the subject the student selected).

For instance, if a student selects mathematics, they are directed to the mathematics resource centre where they have access to different problem-based learning activities for mathematics, inquiry-based learning activities, quizzes, career and mentorship programmes, institutions offering scholarship opportunities, and narratives about amazing women in the field of mathematics. Figure 7.4 displays a screenshot of this.

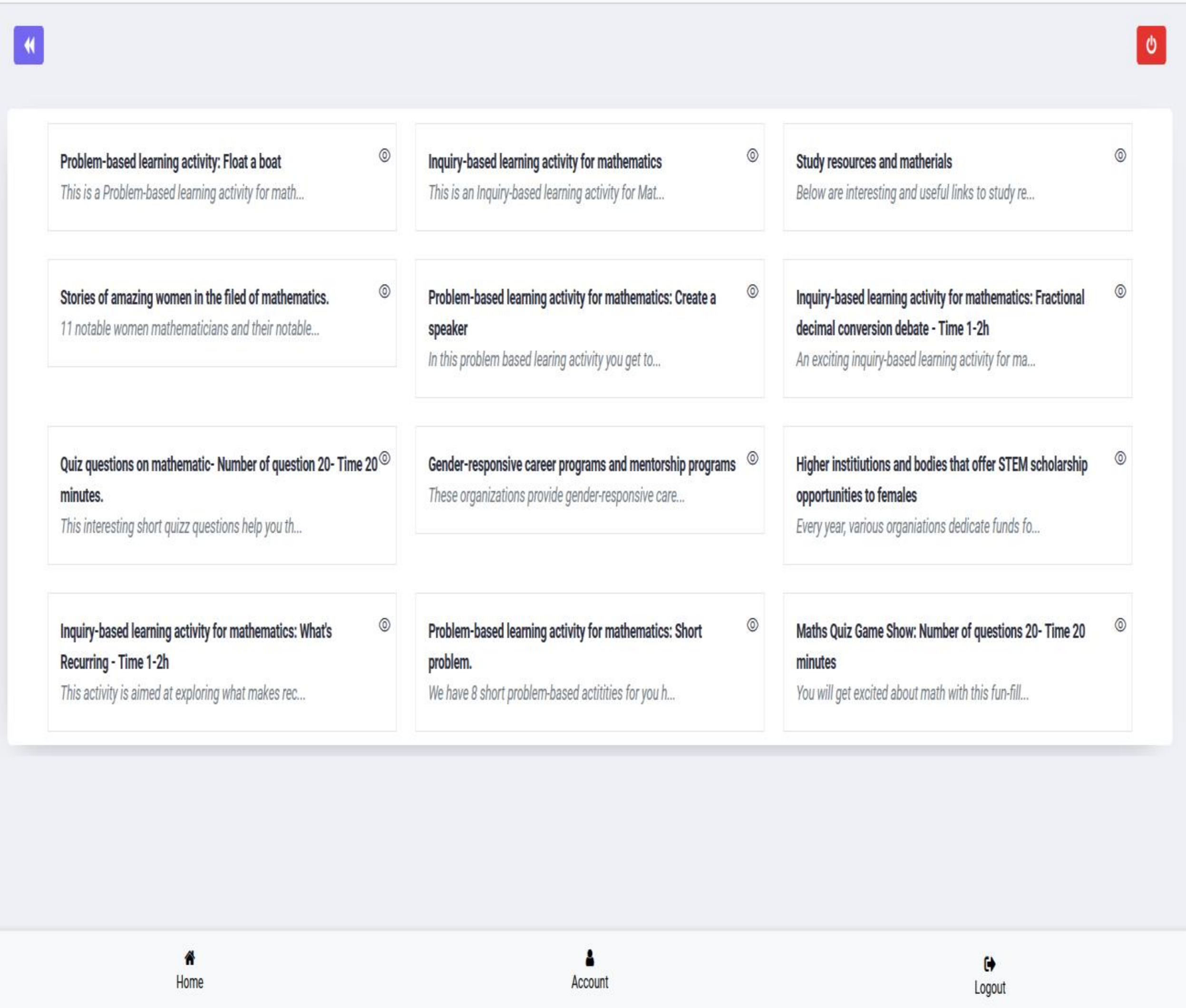

Figure 7. 4: A screenshot of the activities for mathematics in the PET tool.

The activities are such that they allow students to have discussions with other students and STEM personnel, as suggested in the PET4STEM framework. This is a way of creating a social network of learning among like-minded people for them to discern that there are indeed female STEM teachers around. Figure 7.5 shows the screenshot of a problem-based learning activity for mathematics.

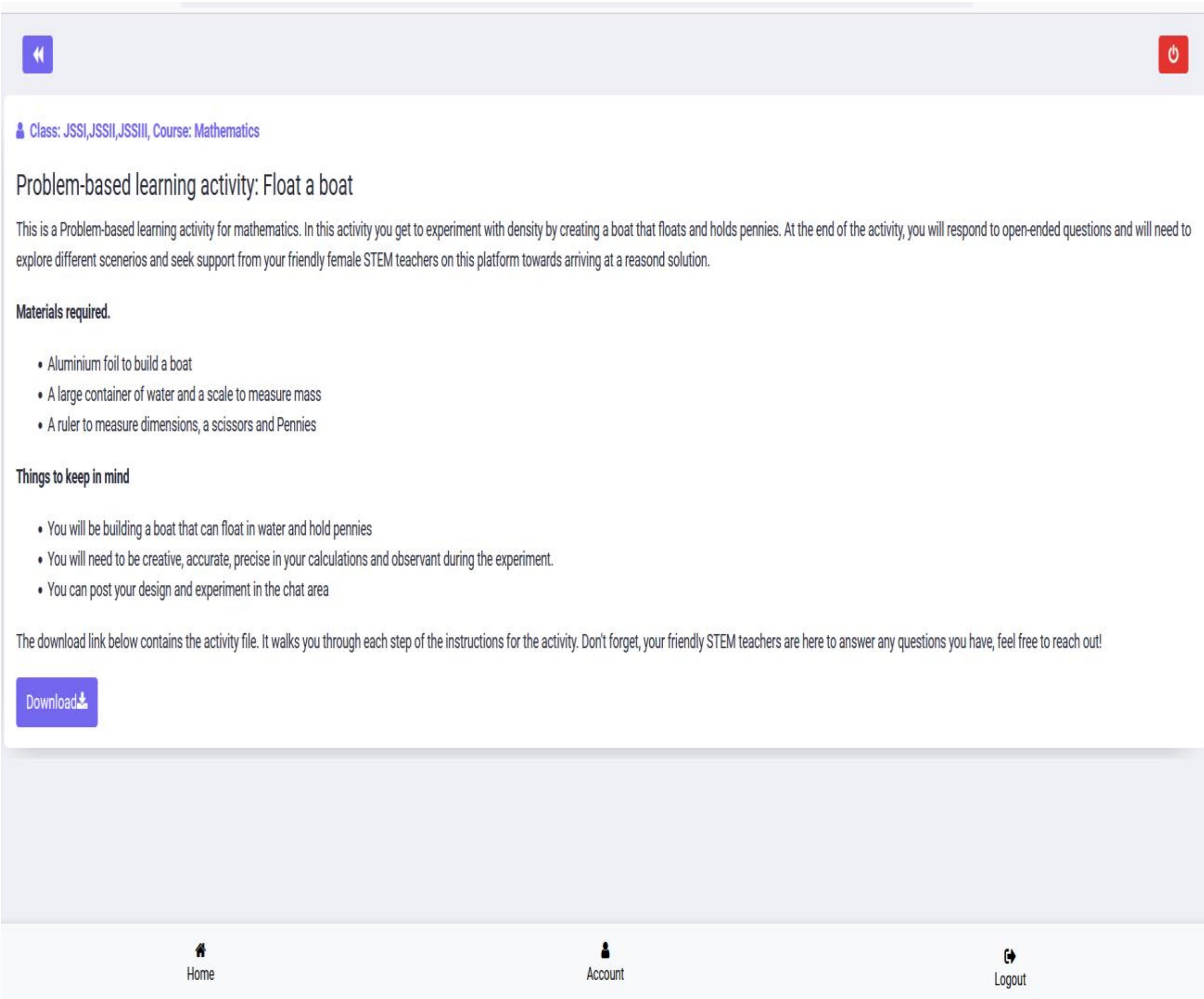

Figure 7. 5: A screenshot of a problem-based learning activity for mathematics.

3. An area for narratives about women in STEM: This third component was implemented to create awareness that STEM fields are not just for men. The component contains narratives about women in STEM generally; it is not specific to any STEM subject. If a student wants to read about women in a specific subject, they will have to navigate to the resource centre for the specific subject and then access the stories of amazing women in that field. These narratives range from very famous women to women doing things that have not been widely recognised. The researcher made sure to include recent narratives about women, even at colleges, who have reported their achievements and recognition in school. The narratives are a mixture of women from Nigeria, Africa and outside Africa. Figure 7.6 is a screenshot of narratives about amazing women in STEM.

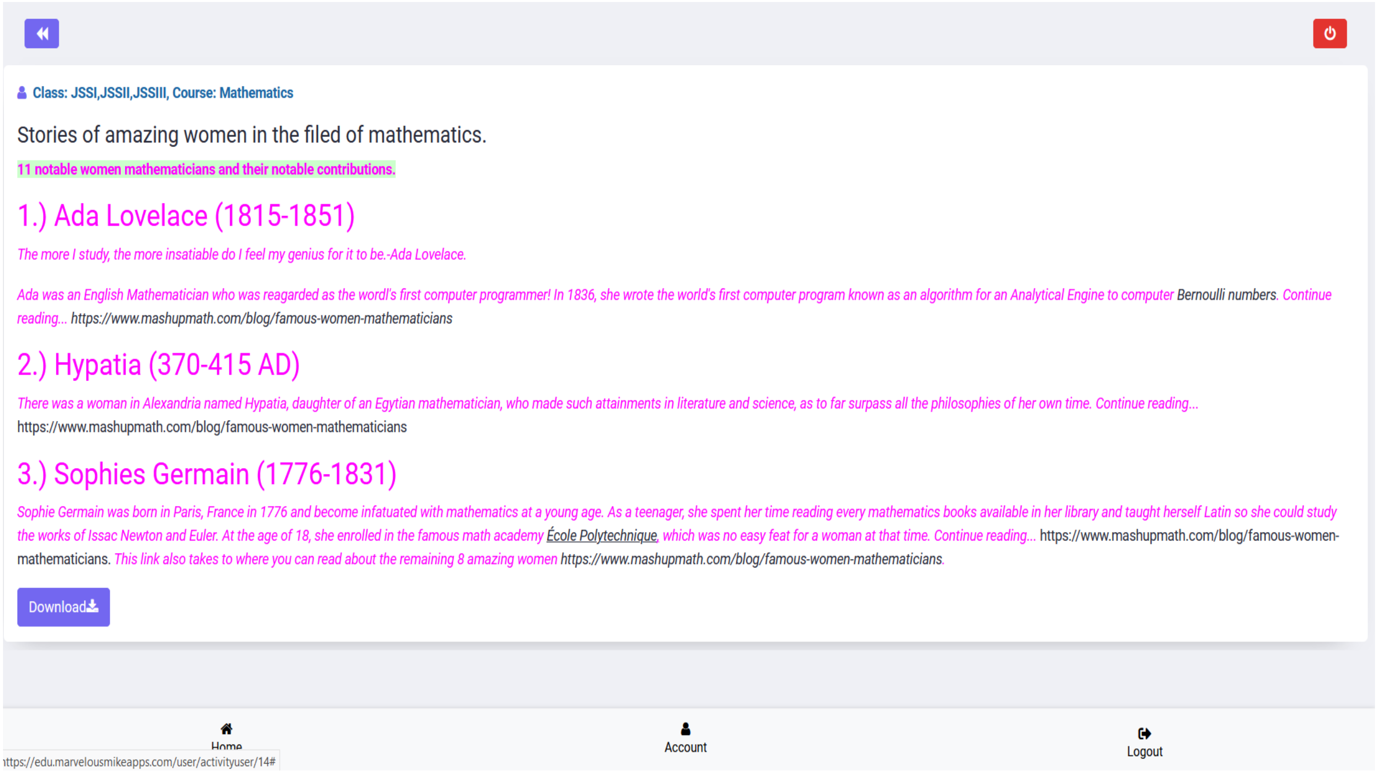

Figure 7. 6: A screenshot of stories of amazing women in STEM.

4. A Game Centre: Educational games were also included in the PET tool. Although games were not suggested in the PET4STEM framework for the barriers in focus. However, Chapter 6 of this study reported that one of the interviewed experts indicated that a framework should allow for some flexibility for the designer to include their imagination in the design. Hence, a game section was added for the researcher to determine how it was accepted by the students. Gamification in learning can lead to more student buy-in, higher levels of engagement, and more diverse learning paths. Learners have also been seen to efficiently achieve learning objectives with added fun (Georgios et al., 2022). Figure 7.7 is a screenshot of the game centre.

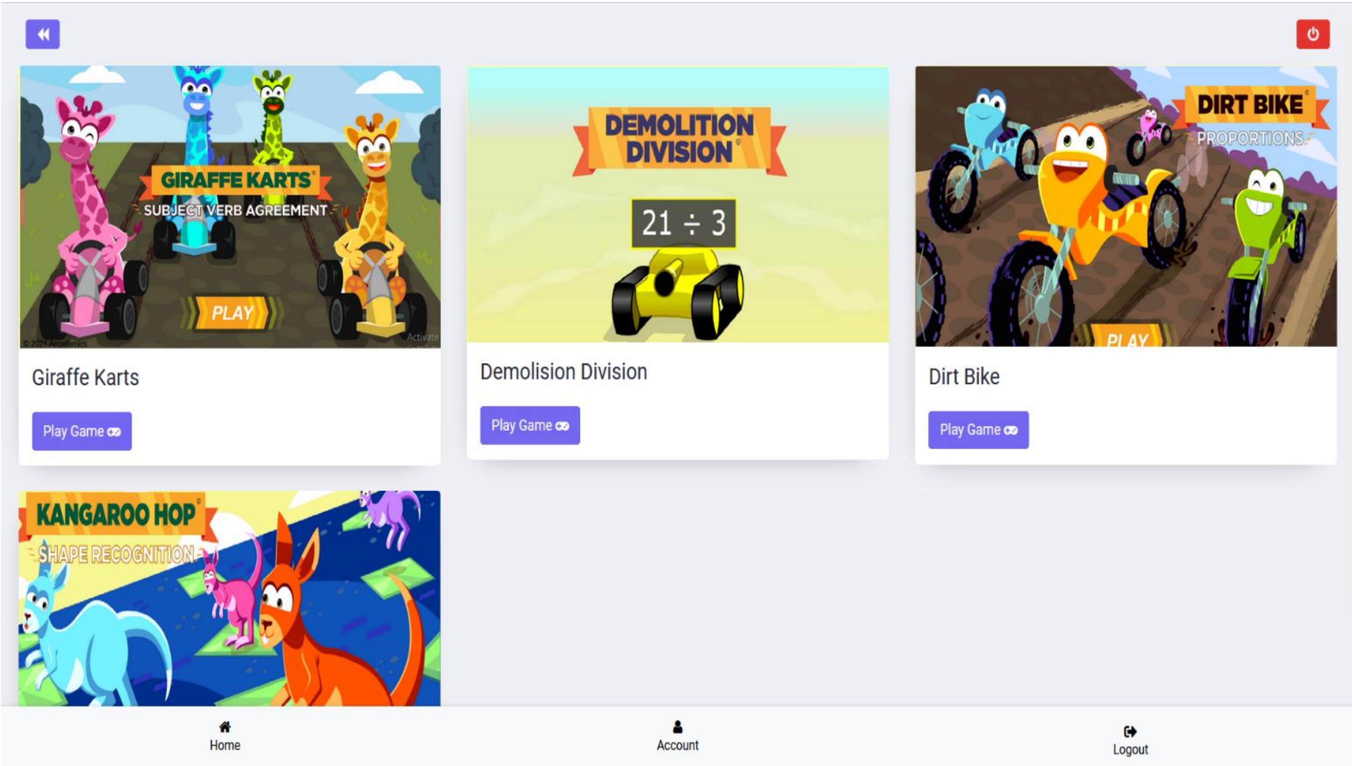

Figure 7. 7: A screenshot of the games centre in the PET tool.

7.7 EVALUATING THE COMPONENTS OF THE PILOT PET APPLICATION WITH THE STUDENTS

The researcher intended to investigate whether female students could successfully and actively engage in STEM learning activities through a PET tool developed using suggestions from the PET4STEM framework. Hence, an interactive web-based PET tool was developed using suggestions from the PET4STEM framework. This tool was developed with the four main components of the PET4STEM framework in mind:

(1) Barriers to junior secondary school female students' choosing a STEM profession: Two barriers from the PET4STEM framework were selected, namely "absence of female STEM teachers" and "societal and parental perceptions that STEM fields are for men". Hence, the researcher intends to find out from the students whether the interactive web-based PET tool has elements that address these factors.

(2) The persuasive strategies that can be used to mitigate the barriers: The social facilitation persuasive strategy, as suggested in the PET4STEM framework, was employed to mitigate these barriers. Hence, the researcher intends to find out from the students whether the interactive web-based PET tool has elements of social facilitation.

(3) The pedagogical approaches that can accommodate the chosen persuasive strategies: The inquiry-based learning approach and the problem-based learning approach were selected for the social facilitation persuasive strategy, as suggested in the PET4STEM framework. Hence, the researcher intends to find out from the students whether the interactive web-based PET tool has elements of the inquiry-based learning approach and the problem-based learning approach.

(4) The technologies that can accommodate the pedagogies for effective delivery of the STEM learning content: The study selected an interactive web-based tool with a chat feature, multimedia content, blog posts, links access, and email access to be developed. Hence, the researcher intends to find out from the students whether the interactive web-based PET tool has elements that qualify it as being interactive.

7.7.1 Female Students' Profiles

Twenty-six female students were purposively selected to participate in the evaluation of the PET4STEM tool. The students were selected from the same three schools that participated in the interview conducted when identifying the components of the framework reported in Chapter 6. The demographics of the students are shown in Table 7.1. For confidentiality purposes, the students are represented as STUDENT-1, STUDENT-2, STUDENT-3, and so on, and their schools are represented as SCH-A, SCH-B, and SCH-C.

Table 7. 1: Demographics of the Students

Total Respondents = 26	
Gender	Female (100%)
Age	11–12 (n=6, 23%), 13–14 (n=6, 23%), 15–16 (n=7, 27%), 17–18 (n=7, 27%)
Class	JSSI (n=8, 31%), JSSII (n=10, 38%), JSSIII (n=8, 31%)
School	SCH-A (n=10, 38%), SCH-B (n=8, 31%), SCH-C (n=8, 31%)

All the students were in junior secondary school (JSSI-JSSIII), and their ages ranged between eleven and eighteen years. Twelve of the students had participated in the previous interview and focus group session reported in Chapter 6; the remaining fourteen students were new participants. There were eight JSSI students, ten JSSII students, and eight JSSIII students. Ten were from School A, eight from School B, and eight from School C. All the students were female. The students used the PET4STEM tool for three weeks.

7.7.2 Responses from the Interview with the Students

The students responded to ten open-ended interview questions. The questions and responses of the students are presented below.

Interview Question 1. What would you say about the platform, does it help you realise that there are female STEM teachers in Nigeria and around the world?

This question was asked to evaluate whether the features in the PET application helped the students realise that there were female STEM teachers in Nigeria and around the world. The students' responses indicated that the tool helped them realise that there were female STEM teachers, not only around the world and in Nigeria, but also in the town where they lived. Excerpts from some students' responses are:

> *Through this learning platform I have met a female STEM teacher in my town. I wish she can become a teacher in my school.* (SCHC-Student 19)
>
> *Yes, the website allowed female teachers to join, and this is good. Honestly, I didn't know there were women that taught metalwork and woodwork. In my school, it's all male teachers.* (SCHA-Student 3)

Interview Question 2. How do you feel about STEM professions, knowing there are female STEM teachers in Nigeria and around the world?

This question was asked to evaluate whether knowing there were female STEM teachers made any difference to the students' perceptions of STEM professions. Their responses indicated that knowing there were female STEM teachers made the profession seem less masculine. Excerpts from some students' responses are:

> *Oh, knowing that there are women STEM teachers makes me now believe that there will be women in several other STEM areas.* (SCHC-Student 23)
>
> *I now know that there are not just females in STEM but that females can excel in STEM, see those STEM teachers are really good at explaining things.* (SCHB-Student 13)

Interview Question 3. How do you feel having a female STEM teacher answer your questions; does it make any difference to your learning and engaging with STEM subjects?

This question was asked to evaluate whether having female STEM teachers teaching female students STEM subjects made any difference to them compared to having male STEM teachers. Their responses indicated that having female STEM teachers made the STEM subjects and STEM professions more relevant. Excerpts from some students' responses are:

> *Yes, just knowing that she must have gone through what I am presently going through, and she is able to become what she is, makes me feel confident about taking a STEM pathway.* (SCHA-Student 10)
>
> *It sure feels different, all the science (referring to STEM) teachers in my school are male. But in this past week, having these friendly tutors take us science makes the subject not intimidating at all.* (SCHB-Student 11)

Interview Question 4. In the platform, you had to engage with the other students and STEM teachers. How do you feel having these options; do they make any difference to your learning and engaging with STEM subjects?

This question was asked to evaluate whether the social interaction encouraged in the PET application, which was a suggested implementation of the social facilitation persuasive strategy, made any difference to their interest in STEM subjects. Their responses indicated that the social interaction afforded in the application increased their engagement and interest in learning STEM subjects. Excerpts from some students' responses are:

> *Because for almost all the activities, you would be asked to ask a STEM teacher if your thoughts are right, it made me focus and pay more attention to the materials. It also made them (referring to STEM personnel) answer even further than you asked. So, you learn even more.* (SCHB-Student 9)
>
> *I eventually started reading even wider than the topics for the activity because I wanted to be able to present my argument very nicely to the other students. I found out that wide reading was relevant for me to present a stronger argument.* (SCHA-Student 4)

Interview Question 5. You had activities with open-ended questions in which you had to explore different solutions before arriving at a reasoned answer; what do you think about such learning activities?

This question was asked to evaluate whether the problem-based learning approach and the inquiry-based learning approach were well suited to accommodate the social facilitation persuasive strategy that was employed in the tool, and whether they made any difference to the students engaging with the STEM subjects. Their responses indicated that the pedagogies employed were well suited to the social facilitation persuasive strategy and the pedagogical approaches increased their engagement and interest in learning the STEM subjects. Excerpts from some students' responses are:

I particularly enjoyed the way the activities were arranged. It made us to think critically about the questions and communicate more frequently amongst ourselves. (SCHC-Student 12)

I was shy to communicate with the helpers (Referring to STEM personnel), but when I realised that I would not progress in the activities, I had to put away the shyness and communicate with them. I later appreciated that such communications were important in learning the subjects. (SCHA-Student 1)

Interview Question 6. There is a chat feature on the platform through which you interact directly with other students and STEM personnel; what is your opinion about this feature with regard to making the platform interactive?

This question was asked to evaluate whether the technological features used to make the tool interactive were able to add some level of interactivity to the tool and whether this made any difference to their engagement with STEM subjects. Their responses indicated that the chat feature made it interactive, but they would have preferred the PET tool to have a video conference feature. Although the video conferencing feature was suggested in the PET4STEM framework, it was not implemented in this tool. Excerpts from some students' responses are:

It was nice to use the chat platform for the debate, we sent videos and voice notes of our debates which gave the STEM personnel the assurance that we researched the activity. But it would have been better to have a live video conference feature. (SCHB-Student 15)

I was pleased with the chatting platform; it made the application very interactive. (SCHC-Student 26)

Interview Question 7. There is a blog feature on the platform through which you view and gain access to links on STEM career and mentorship programmes. Did you access any of these programmes; if yes, what is your opinion about this feature with regard to it helping you gain access to platforms where you can clear your misconceptions about STEM professions?

This question was asked to evaluate whether there was any benefit in providing students with information about STEM careers and mentorship programmes and whether accessing such programs (which is another suggested implementation of the social facilitation persuasive strategy) helps students discern that STEM fields are for everyone.

Their responses indicated that the students were not sufficiently confident to access such programmes by themselves. They expressed that they would prefer to have a grown-up with them before accessing the programmes. Of twenty-six students, only two students used the links. One of them indicated that she was waiting for an upcoming information session from one of the programmes, and the other indicated that she had already attended an information session about what the programmes entailed, what they offered, the types of programmes they ran, and they answered other questions by young women like her from developing African countries. The response of the girl who had attended an information session indicated that it was a good feature of the PET tool. Excerpts from these two students' responses are:

> *I did, I was curious to know what these programs offer. I registered with ... (name of mentorship program) ... it's a Nigerian-based NGO. I am waiting for the orientation or information program.* (SCHA-Student 6)
>
> *The one I attended was ... (name of mentorship program[me]) ... It was very informative. There were lots of Nigerians who attended. I didn't ask any questions because so many girls asked all the questions I had. I learned it's free and girls can later be assigned to private mentors if they want.* (SCHC-Student 22)

With the low number of students who accessed the link, it would be better to allow a login option for parents or guardians of the students for activities like these, which the young women were not sufficiently confident to access by themselves.

Interview Question 8. There are links to institutions that offer scholarship opportunities to female students; did knowing about these scholarship programmes help you realise that STEM fields were not just for men?

This question was asked to evaluate whether there was a benefit in providing students with information about STEM scholarship opportunities for female students and whether knowing such opportunities, which are also the suggested implementation of the social facilitation persuasive strategy, helped the students realise that STEM fields were for everyone.

Their responses indicated that this feature made them realise there was a larger community that advocated and encouraged women to pursue STEM professions. They expressed that the way their communities portrayed STEM convinced them that the STEM profession was for men but knowing about such opportunities made them think differently. Excerpts from some students' responses are:

> *Who would have thought that there was this much encouragement from the wider society? This is totally different from what we see in our own places (meaning in their*

own small societies). It's important to let young girls in school know about this, because it will encourage us a lot to pursue our dreams. (SCHB-Student 4)

It was a positive experience because I didn't even think that in Nigeria girls are encouraged this much to take STEM professions. I thought it's only in the Western countries. (SCHA-Student 10)

Interview Question 9. If you are given the chance to use the platform again, what would you like to be added or removed from the platform?

This question was asked to evaluate whether there was any feature in the tool that the students were not comfortable with or that they felt should have been offered differently. Their responses indicated that they were pleased with what the tool offered. However, some students (eight of them) reiterated that a live video feature would have made it more interactive. Excerpts from some students' responses are:

Oh, no. I don't have anything to add or remove. I am satisfied with its content. (SCHA-Student 7)

I was recording one of my points for the debate I had in one of the activities and my phone died. If it was a live call (referring to video conference), I would have already made my point. So, I would like that to be added. (SCHB-Student 14)

Interview Question 10. Overall, were you comfortable using the platform, and was using the platform enjoyable to you?

This question was asked to evaluate the overall acceptance of the idea of the PET tool and if the features used were in any form coercive or irrelevant. Their responses indicate that they had positive user experiences. None of the 26 students had any negative comments. No one reported any unpleasant or boring experience throughout the three weeks of using the app. Excerpts from some students' responses are:

I enjoyed using the app, it was very useful to me. (SCHB-Student 18)

This initiative is very relevant to me because it has really built my self-confidence in STEM subjects. I enjoyed it. (SCHA-Student 2)

7.7.3 Analysing the Responses of the Students Using the Attention, Relevance, Confidence and Satisfaction Model

The responses of the students were further analysed using the attention, relevance, confidence and satisfaction (ARCS) model (Keller, 1987). ARCS is a model that evaluates learners' motivational perceptions of instructional approaches, technologies or interventions using four dimensions of motivational constructs: attention, relevance, confidence and satisfaction (Ma & Lee, 2021). The authors of the model claimed that these four constructs were derived from a review and synthesis of studies and theories concerned with motivational concepts. Since its design, the ARCS model has been accepted and widely used to guide the design and evaluation of various learning interventions in several fields to ensure learners' continued motivation (Kun & Keller, 2018; Turel & Sanal, 2018; Hao & Lee, 2021). In the literature review conducted in Chapter 2 of this study, studies that used the ARCS model to evaluate their intervention were included in the review. This indicates how widely used the ARCS model is.

According to Keller (1987), the attention component refers to the extent to which the intervention arouses learners' curiosity and sustains their attention over time. The relevance component focuses on the extent to which the intervention aligns with or is useful to the learners' personal goals. The confidence component relates to how much the intervention can enhance learners' confidence by helping them believe that success can be achieved through personal effort and control. Lastly, the satisfaction component is concerned with evaluating to what extent the learners are satisfied with the intervention at the end of the learning experience.

In the software tool used for the analysis of participants' responses, *Atlast.ti.*, one can find the most frequently mentioned noun in single or multiple documents, and then the nouns can be reviewed in their surrounding context in the quotation reader to analyse its relevance to the study further; this is most known as concept search. A concept search was done to identify if the students used words relating to any of the four motivation constructs of the ARCS model and whether the usage of the words was in the context of motivation towards STEM. To achieve this, the responses of each student were grouped based on the interview questions, so there were ten different documents, each containing the responses of all the respondents to a specific interview question. Each of these documents was named RESPONSE-1, RESPONSE-2, RESPONSE-3, and so on, up to RESPONSE-10 for each of the interview questions. For each of these documents, a concept search was conducted to identify the most frequently mentioned noun.

1. For the first interview question, the most frequently mentioned nouns in the students' responses were not related to any of the ARCS constructs.
2. For the second interview question, the most frequently mentioned nouns in the students' responses were also not related to any of the ARCS constructs.

3. For the third interview question, two of the most frequently mentioned nouns were related to the Relevance and Confidence constructs of the ARCS model. The words used for the Confidence construct and their frequencies were confidence (27), self-confidence (19) and self-assurance (16). For the Relevance construct, they were relevance (12), significance (11) and important (11). Further analysis revealed that they were used in the context of motivation for STEM professions.
4. For the fourth interview question, two of the most frequently mentioned nouns were related to the Attention and Relevance constructs of the ARCS model. The words used for the Attention construct and its frequency were, attention (15), while for the Relevance construct, they were, relevance (13), central (11) and important (10). Further analysis revealed that they were used in the context of motivation for STEM professions.
5. For the fifth interview question, two of the most frequently mentioned nouns were related to the Attention and Relevance constructs of the ARCS model. The words used for the Attention construct and their frequencies were careful (11), thinking (19) and focused (9). For the Relevance construct, they were relevance (23), crucial (19), and most important (10). Further analysis revealed that they were used in the context of motivation for STEM professions.
6. For the sixth interview question, two of the most frequently mentioned nouns were related to the Confidence and Satisfaction constructs of the ARCS model. The words used for the Confidence construct and their frequencies were assurance (22), certainty (20), and confidence (17), while for the Satisfaction construct, they were pleased (13), satisfied (13) and grateful (11). Further analysis revealed that they were used in the context of motivation for STEM professions.
7. For the seventh interview question, the most frequently mentioned nouns were not related to any of the ARCS constructs.
8. For the eighth interview question, two of the most frequently mentioned nouns were related to the Relevance and Confidence constructs of the ARCS model. The words used for the Relevance construct and their frequencies were useful (16), appropriate (11), and sensible (8), while for the Confident construct, they were assured (13), positive (11) and confident (19). Further analysis revealed that they were used in the context of motivation for STEM professions.
9. For the ninth interview question, the most frequently mentioned nouns were not related to any of the ARCS constructs.

10. For the tenth interview question, three of the most frequently mentioned nouns were related to the Relevance, Confidence, and Satisfaction constructs of the ARCS model. The words used for the Relevance construct and their frequencies were relevance (26), useful (22), and meaningful (19). For the Confidence construct it was self-confidence, while for the Satisfaction construct, they were enjoyed (27), and happy (23). Further analysis revealed that they were used in the context of motivation for STEM professions.

Table 7.2 summarises the ten interview questions and the most frequently used words in response to the questions.

Table 7. 2: Interview Questions and the Most Frequently Used Nouns in the Responses.

	Interview Questions	**Frequently used nouns related to the ARCS construct.**
1.	What do you say about the platform; does it help you realise that there are female STEM teachers in Nigeria and around the world?	None
2.	How do you feel knowing that there are female STEM teachers in Nigeria and around the world?	None
3.	How do you feel having a female STEM teacher answer your questions; does it make any difference to your learning and engaging with STEM subjects?	**Relevance:** relevance (12), significance (11) and important (11). **Confidence:** confidence (27), self-confidence (19) and self-assurance (16).
4.	In the platform, you had to engage with the other students and STEM teachers. How do you feel having these options; do they make any difference to your learning and engaging with STEM subjects?	**Attention:** attention (15). **Relevance:** relevance (13), central (11) and important (10).
5.	You had activities with open-ended questions in which you had to explore different solutions before arriving at a reasoned answer; do such learning activities make any difference to your learning and engaging with STEM subjects?	**Attention:** careful (11) thinking (19), focused (9) **Relevance**: relevance (23), crucial (19) and appropriate (10). Further analysis revealed that they were used in the context of motivation for STEM professions.

6.	There is a chat feature on the platform through which you interact directly with other students and STEM personnel; what is your opinion about this feature with regard to making the platform interactive?	**Confidence**: assurance (22), certainty (20) and confidence (17). **Satisfaction:** pleased (13), satisfied (13) and grateful (11).
7.	There is a blog feature on the platform through which you view and gain access to links on career and mentorship programmes. Did you access any of these programmes; if yes, what is your opinion about this feature with regards to it helping you gain access to platforms where you can clear your misconceptions about STEM professions?	None
8.	There are links to institutions that offer scholarship opportunities to female students; does knowing about all these scholarship programmes help you realise that truly STEM fields are not just for men?	**Relevance:** useful (16), appropriate (11) and sensible (9). **Confidence:** assured (13), positive (11) and confident (19).
9.	If you are given the chance to use the platform again, what would you like to be added or removed from the platform?	None
10.	Overall, were you comfortable using the platform, and was using the platform enjoyable to you?	**Relevance:** relevance (26), useful (22) and meaningful (19). **Confidence:** self-confidence (18). **Satisfaction:** enjoyed (27), happy (23).

The frequent occurrence of related words from the ARCS models suggests that if a full-scaled PET tool is developed following the suggestions of the PET4STEM framework and used for a longer period, there is potential for the tool to change junior secondary school female students' attitudes towards STEM subjects and their perception about STEM professions, and, consequently, their decision to pursue STEM professions.

7.8 EVALUATING THE PILOT PET TOOL AND PARTICIPATION OF THE STUDENTS BY THE STEM PERSONNEL

The interview with the STEM teachers and personnel who participated in the three-week intervention was intended to gather their personal experiences and reflections about the PET tool and their assessment of the students' participation in the three-week intervention. This was intended to gauge how the idea of the PET tool was perceived by the teachers and personnel and their thoughts about the students' engagement on the platform.

7.8.1 STEM Personnel Profiles.

Six participants were purposively selected for the intervention. These participants were selected based on their capability and willingness to answer questions from the junior secondary school students. These women were all of Nigerian origin, but most were based in the diaspora. Nigerians were used because we wanted the junior secondary school students to resonate well with them. The women had similar names and shared similar backgrounds with the students in terms of language and culture. Table 7.3 displays the demographics of the participants. For confidentiality purposes, the participants are represented as PERSON-1, PERSON-2, PERSON-3 and so on.

Table 7. 3: Demographics of the Personnel.

Interviewee	Profession/Current position	Highest level of education	Age	Place of work	Country	Gender
PERSON-1	Mathematics teacher	Undergraduate	31	Secondary school.	Nigeria	Female
PERSON-2	Physics teacher	Undergraduate	27	Secondary school.	Nigeria	Female
PERSON-3	Doctoral student in Chemistry	Undergraduate	32	Bayero University, Kano.	Nigeria	Female
PERSON-4	Postdoctoral student in Architecture	Doctoral Degree	41	University of technology.	Malaysia.	Female
PERSON-5	Computer engineer	Master's Degree	29	Canada post	Canada.	Female
PERSON-6	Associate professor in Computer Science.	Doctoral Degree	45	University of Dalhousie.	Canada.	Female

7.8.2 Responses from the Interview with the STEM Personnel

The findings from the interview indicated that they appreciated the idea of the concept of the PET tool as a tool to change junior secondary school female students' attitudes towards STEM. They expressed that the students showed much curiosity about their challenges as STEM practitioners, which is an indication of them resonating with the female personnel and teachers. They also emphasised that the students were enthusiastic about participating in the activities, which they indicated was because they were all female personnel on the platform. Excerpts from the teachers' and personnel's responses are:

> *Honestly, I have always wished for some platform like this for young girls. The idea is awesome …* PERSON-3
>
> *This is what young ladies need. More encouragement from mentors who they can relate with. I met a student on the platform who is from my hometown, and she told me she heard stories about me but wasn't sure whether to believe it or not. But meeting me now, she is determined to work hard to make the name I have made …* PERSON-4
>
> *I know you mentioned that the meaning of PET is a persuasive education tool, that name scared me a bit. I thought the students were going to be pressured in some way, but to my surprise, this is a pleasant form of persuasion. The contents were not forceful but deliberate and well-structured. It should be introduced to schools like mine…* PERSON-1
>
> *I had my story amongst the stories of awesome STEM women, and I noticed that almost all the students chose me as a favourite chat person. Wow! I had lots of questions to answer (laughs). This is an indication that our girls want to interact with people like us, it's motivating to them. (…) They asked lots of questions which is simply because I was like them, hence the ease in communication.* PERSON-5
>
> *I was surprised to see our girls are curious and vocal. They aren't usually like this in class. They were more comfortable in this online space. I think this is an excellent way to get them to engage well with STEM subjects.* PERSON-2
>
> *The student kept the platform busy throughout the entire three weeks. I was glad I was off work while this intervention was going on. They wanted feedback on their debates, they had lots of questions about my challenges, and they want to know if I thought they would make it in STEM. So, many questions that indicated these young girls need mentors around them. We need to get more mentors when you fully launch this app.* PERSON-6

7.9 A COMPARISON OF THE PERSUASIVE EDUCATIONAL TECHNOLOGY TOOL TO RELATED TOOLS

The PET tool follows design suggestions from the PET4STEM framework, hence, its strength compared to other related tools are the strength that the PET4STEM framework has compared to the frameworks reviewed in Chapter 3 of this study (see section 6.2.6). This is because most tools available in literature employed the frameworks reviewed in Chapter 3 of this study (Murillo-Munoz et al., 2018).

For example, in this PET tool, the persuasive strategies employed were tailored to the specific problems that the tool intended to tackle. According to Alslaity et al. (2024) tailoring persuasive strategies to specific contexts or individual characteristics enhances the efficacy of the strategy. Conversely, Engelbertink et al. (2020) who designed a PET tool for a course named autobiographical reflection for second-year social work students which was meant to contribute to the development of their professional identity did not tailor the strategies they employed to the specific problems they identified as barriers to having an enhanced professional identity. This was the same in Krishnamoorthy and Merchant (2023), they implemented the strategies as suggested in the PSD framework in their PET without intentionally adapting the strategy for any specific problem.

One of the disadvantages of not tailoring a persuasive strategy is that the designer will not know which strategy or what combination of strategies accomplished what task. In this current PET tool, the researcher, for example, knows that the social facilitation persuasive strategy was employed to help the female students discern that there were other females involved in teaching STEM subjects and the evaluation results showed that the strategy helped to achieve this aim. Hence, whenever a designer needs to redesign, update, enhance, or even develop a new PET tool, they know what strategies are most suited to what tasks.

Another strength of this current PET tool is the deliberate integration and careful selection of the pedagogical approaches in the tool. The pedagogical approaches were chosen specifically for the strategies. This ensured that there was no conflict between what the strategy was going to provide and what the pedagogical approach could accommodate. For example, the inquiry and problem-based learning pedagogies, which are approaches that foster a high level of interaction between learners and educators, were selected to accommodate the social facilitation persuasive strategy. It would be recalled that the social facilitation persuasive strategy was meant to help the students discern that there are females who teach STEM subjects. The kind of task that the students had to perform was such that they had to communicate with personnel on the platform and by doing so, they found out that all the personnel on the platform were females. This is unlike the study of Muhammad et al. (2023) who designed PET to keep students motivated on an e-learning platform, there was no mention of any pedagogical approach that guided the delivery of the educational content in the tool. Likewise, Qasim et al. (2018) who designed a PET for primary school students to overcome their anxiety towards mathematics. This should be an important aspect of the PET especially that their tool was developed for primary school students because the sequencing of instructional content and connection of ideas for very young students needs some level of pedagogical sophistication to achieve. One disadvantage of not selecting a pedagogy is that the learning activities in the tool might not be deliberate, which might cause the designer of the tool to lose focus from the aim of the tool, hence users will be occupied with irrelevant tasks that distracts from the goal.

This is the same with the technological platform selected for the PET tool designed in this study. It is imperative to select a technology that can accommodate the persuasive strategies chosen in a PET for the effective delivery of the instructional content. Most tools in available literature did not mention that the technology that their PET was designed to assume was chosen deliberately to enhance the delivery of content in the PET. This was the case in the PET reviewed in Kastelli and Takács (2023) and the study conducted by Ndulue and Orji (2018) who designed a PET called STD Pong to educator youths about risky sexual habits. One plausible reason for this might be that no attention was given to the pedagogical aspect of these tools. After all, the framework they followed did not provide any information regarding pedagogies. These strengths discussed may be few, but they go a long way in making PETs more focused and hence effective. The next section summarises this chapter.

7.10 SUMMARY

This chapter presented a pilot PET tool that was developed following the PET4STEM framework designed in the previous chapter. A pilot tool was developed because of the limited time left for the study to develop and evaluate a full-scale tool. The use of the PET tool by students and STEM personnel lasted only three weeks, and, according to Prieto-Rodriguez et al. (2020), such short-term interventions are not capable of capturing the constructs that are indicative of an intention to enrol in STEM disciplines in the future. Hence, the reason for a pilot tool.

The pilot PET tool targeted two barriers to female students' enrolment into STEM pathways, namely the "absence of female STEM teachers" and "societal and parental perception that STEM fields are for men". After using the tool for three weeks, the researcher investigated whether the features of the pilot PET tool allowed the students to engage and enjoy learning STEM subjects and the STEM personnel's opinions about the idea of the PET tool. The results from the interview suggested that the components of the pilot PET tool delivered what they were intended to.

Students found the features motivating towards becoming aware that there are female STEM teachers in Nigeria and around the world and that STEM fields are not just for men, which changed their perception of STEM professions. They also found the pedagogical activities, i.e., problem-based learning and inquiry-based learning, very engaging and relevant to changing their perception of STEM professions. Lastly, they found the interactive web-based tool features such as the chat, email, links and blogs closely aligned with the activities on the platform and had a positive user experience with these features.

The analysis of the most frequent nouns the students used to describe their experiences on the platform was found to relate to the construct used to define motivation in the ARCS model. The interview with the STEM teachers and personnel also revealed that the students were enthusiastic about learning while the female personnel were accessible and that the tool's features were ideal for the students and the barriers they targeted. The results in this chapter are an indication that if a full-scaled PET tool was developed following the suggestions of the PET4STEM framework, there is potential for the tool to change junior secondary school female students' attitudes towards STEM subjects and, consequently, their decision to pursue STEM professions in the future. The next chapter discusses the thesis contribution and specific recommendations for PT designers.

CHAPTER 8: RESEARCH OVERVIEW, LIMITATION, AND CONCLUSION

8.1 INTRODUCTION

The previous chapter reported on the implementation and evaluation of the PET4STEM framework. Twenty-six female learners in junior secondary classes and six STEM personnel were recruited to use the PET tool that was developed following suggestions from the PET4STEM framework. The findings from the three-week evaluation indicated that a full-scale PET tool developed following suggestions from the PET4STEM framework has the potential to change junior secondary school female learners' attitudes toward STEM subjects and consequently their decision to pursue STEM professions in the future. This chapter, thus, summarises and concludes the research project.

The rest of the chapter is organized as follows. Section 8.2 begins with an overview of the research study where a summary of each chapter of the thesis and its key takeaway is presented as a reminder of what was done. Section 8.3 then reflects on the entire study by stating the main research question and the sub-questions and discussing what was realized from each sub-question. This is followed by section 8.4 which presents the theoretical, empirical and practical contributions of the study. Section 8.5 then discusses the limitations of the study and the future works that can be done to fill these limitations. The recommendations of the study are presented in section 8.6 and lastly a conclusion section in 8.7.

8.2 RESEARCH OVERVIEW AND SUMMARY OF THE KEY TAKE AWAY OF EACH CHAPTER

This thesis consists of eight chapters. Chapter 1 established the context of the research, providing the research problem, the scope of the research, the methodological approaches that guided the research, and the expected contribution of the research study. The research problem was the increase in the demand for STEM skills and the need to motivate more women to meet the demand in Nigeria. A framework to guide the design of persuasive educational technology was proposed to be designed to help solve this problem.

Chapter 2 was a literature review conducted to understand why female students choose non-STEM professions over STEM professions and what prior studies did regarding motivating women to pursue STEM professions. It was deduced that contextual and individual factors work in tandem to affect female students career choice. Meanwhile, existing interventions to motivate young women to take up STEM profession often assume female students possess some personal qualities which require correction for them to be able to enrol in STEM disciplines. This chapter then argued that interventions need to identify and help young women challenge the discriminatory practices and values in their environment that assumes their unfitness for STEM. Hence, a persuasive educational technology was claimed to have the potential to do so.

Chapter 3 was a literature review conducted to understand how persuasive technologies (PT) can be used to change female students' attitudes toward STEM professions to increase their enrolment in STEM pathways. Existing PTs and PT frameworks were reviewed to see what has been communicated regarding persuasive strategies, system features, and technological platforms used to achieve attitude change. It was deduced that existing framework are generic, making them unsuitable for providing detailed suggestions about a learner, a learning content, context and learning constraints. Hence a context specific framework was suggested to be best for the problem identified in this study.

Chapter 4 covered the conceptual foundation that directed the creation of the PET4STEM framework. The conceptual idea was that environmental factors and individual factors collaborate to influence students' attitudes towards STEM subjects, which, in turn, influence their decision to enrol into STEM disciplines and a PET tool can counter the effect of external and internal factors to engender a positive attitude towards STEM in students. But for a PET tool to effectively counter these effects, the designer needs to have a knowledge of the factors that affect their audience's enrolment into STEM, the persuasive strategies that they are susceptible to, the pedagogical approaches to employ, and the technological platform the PET can assume.

Chapter 5 discussed the research methodology, describing how the research was conducted. It indicates that the philosophical stance of the study was interpretivism and the research strategy was DSR. The data was collected using interviews and a focus group and was analysed qualitatively.

Chapter 6 discussed the development of the actual PET4STEM framework based on data from the interviews and a focus group session conducted among junior secondary school female students, STEM teachers, and STEM experts. The PET4STEM framework provided detailed design suggestions regarding (i) the barriers that affect female students' enrolment into STEM disciplines, (ii) the persuasive strategies that the females are more susceptible to, (iii) the teaching and learning approaches that can accommodate the persuasive strategies and are suited to teaching STEM subjects, and (iv) the technologies that can accommodate the teaching strategies for effective delivery of the instructional contents.

Chapter 7 reported on the design and evaluation of an actual PET tool following the suggestions from the PET4STEM framework. The tool targeted two barriers to female students' enrolment into STEM pathways, namely the "absence of female STEM teachers" and "societal and parental perception that STEM fields are for men". Students and STEM personnel used the tool for three weeks, after which the researcher investigated whether the features of the tool allowed the students to engage and enjoy learning STEM subjects. The STEM personnel's opinions about the idea of the PET tool were also investigated. The results from the interview suggested that the components of the tool had the potential to foster a positive attitude toward STEM subjects and professions among young Nigerian female learners.

8.3 REFLECTION ON THE RESEARCH QUESTIONS AND OBJECTIVES

This section reflects on the research questions and objectives to understand what the study aimed to achieve, what was accomplished, and how it was accomplished.

This study aimed at developing a PET4STEM framework that guides the design of PET tools that would be used to motivate junior secondary school female students in Nigeria to enrol in STEM pathways, which led to the formulation of the main research question: How can a PET-based framework for motivating junior secondary school female students in Nigeria to enrol in STEM be designed (Section 1.5)?

The main research question was addressed via several sub-research questions and objectives listed in Chapter 1 (Sections 1.4 and 1.5).

The first sub-research question that the study aimed to answer was:

- What factors influence enrolment into STEM classes by junior secondary school female students in Nigeria as they transition into senior secondary school?

The related research objective was:

- To identify the factors that influence enrolment into STEM classes by junior secondary school female students in Nigeria when they transition to senior secondary school.

The first sub-research question, and related objective, were answered through the literature review conducted in Chapter 2 and the interview sessions conducted in Chapter 6. From the review of both theoretical and empirical literature (Section 2.7), it was realized that individual, family, school, and cultural factors influence female learners' attitudes toward STEM disciplines, and their attitude, in turn, influences their decision to enrol in STEM classes as they transition into senior secondary school.

To get the specific individual, family, school, and cultural factors that influence junior secondary school female learners in Nigeria, interviews were conducted among junior secondary school female learners, STEM teachers, and STEM experts. The interviews revealed that the school factors that hinder female learners from choosing a STEM path include the absence of female STEM teachers, teachers' lack of expertise in explaining STEM concepts, and insufficient educational materials for practical work in STEM classes (Section 6.2.2.1). The cultural factor that hinders female learners from choosing a STEM path is the societal gender role belief that STEM professions are only suitable for men (Section 6.2.2.2). The family factor that hinders female learners from choosing a STEM path is parents' perception of STEM being for males (Section 6.2.2.3). Lastly, the individual factor that hinders female learners from choosing a STEM path includes STEM professions being things-oriented, lack of social belonging, and lack of motivation (Section 6.2.2.4).

The second sub-research question that the study aimed to answer was:

- What persuasive strategies could be effective in motivating junior secondary school female students in Nigeria to enrol in STEM classes?

The related research objective was:

- To investigate which of the available persuasive strategies would be effective in motivating junior secondary school female students in Nigeria to enrol in STEM.

The second sub-research question, and related objective, were answered through a literature review conducted in Chapter 3 and the interview sessions conducted in Chapter 6. In Chapter 3 existing PTs and PT frameworks were reviewed to see the persuasive strategies, and system features used to achieve attitude change (Section 3.7). The most used persuasive strategies in the education domain and in STEM-related PT tools were identified and reported in Chapter 3 of this study.

In Chapter 6 an interview was then conducted among female learners, STEM teachers, and STEM experts to narrow down what was identified in Chapter 3. More specific persuasive strategies that are most suited to junior secondary school female learners in Nigeria and are suited to teaching STEM subjects were identified (Section 6.2.3). The strategies are Social facilitation, Social-role, Similarity, Reduction, Tunneling, Self-monitoring, Suggestion, Collaboration, Expertise, Reliability, Rehearsal, Simulation, Authority, Verifiability, Likening, Role model, Personalization, Reduction, Social proof, Tunnelling, Competition, Reward, Scarcity, Commitment, and Self-monitoring persuasive strategies.

The third sub-research question that the study aimed to answer was:

- How can a PET4STEM framework for a persuasive educational technology-based tool for motivating junior secondary school female students in Nigeria to enrol into STEM classes when they transition to secondary school the design science research approach be designed?

The related research objective was:

- To utilize a Design Science Research approach to develop the PET4STEM framework for a persuasive educational technology-based tool aimed at motivating junior secondary school female students in Nigeria to enrol into STEM classes when they transition to secondary school.

The third sub-research question, and related objective, were answered in the conceptual framework developed in Chapter 4 which was a product of the literature review conducted in chapters 2 and 3. The literature reviewed in Chapters 2 and 3 led to the emergence of the four important components that PET designers should consider when designing PETs to promote junior secondary school female learners in Nigeria to pursue STEM professions. These components are (i) the factors that influence female students' enrolment into STEM disciplines, (ii) the persuasive strategies that the females are more susceptible to, (iii) the teaching and learning approaches that can accommodate the persuasive strategies and are suited to teaching STEM subjects, and (iv) the technologies that can accommodate the teaching strategies for effective delivery of the instructional contents.

To gather more specific information to inform each component of the interviews were conducted among students, STEM teachers, and STEM experts. Following the iterative phases of the Design Science Research the PET4STEM framework went through four phases before a final framework was presented (Section 6.5).

The first phase involved interviewing junior secondary school female students and inquiring about elements of the four key components identified in the conceptual framework. The information gathered from the junior secondary school students was used to develop an initial PET4STEM framework (Section 6.2.6).

The second phase involved presenting the initial PET4STEM framework to the STEM teachers and interviewing them as to whether they resonated with the information in the framework and whether they had any inputs to be made. The information gathered from the STEM teachers was used to develop an intermediate PET4STEM framework (Section 6.3).

The third phase involved presenting the intermediate PET4STEM framework to the STEM experts and interviewing them as to whether they resonated with the information in the framework and whether they had any inputs to be made. The information gathered from the STEM experts was used to develop a penultimate PET4STEM framework (Section 6.4).

The fourth phase and final phase involved going back to the junior secondary school female students and presenting the penultimate PET4STEM framework to them in a focus group session. They were asked if they were pleased with the information provided by the STEM teachers and experts. The information gathered was used to redesign the penultimate framework and this led to the development of the final PET4STEM framework (Section 6.5).

8.4 RESEARCH CONTRIBUTION

The contributions of this research to the body of knowledge include theoretical, empirical, and practical contributions. These contributions are described in this section.

8.4.1 Theoretical Contribution

At a theoretical level, the study provides a new framework, informed by the DSR approach, that consists of the important components that PT designers can consider when designing PTs for promoting STEM enrolment among junior secondary school female learners in Nigeria. As far as the researcher is concerned no study exists in Nigeria that has developed a framework for the design of PTs for promoting STEM enrolment among junior secondary school female learners in Nigeria. Also, existing PT frameworks that were designed outside the Nigerian context fall short of providing context-specific guidelines making them very generic and difficult to apply to specific persuasion contexts (Oinas-kukkonen & Harjumaa, 2009; Wiafe, 2016; Murillo-Muñoz et al., 2021)

With the increasing demand for STEM professions and the shortage of personnel to meet the demand (Umar, 2019; Sulai & Erasmus, 2022), a context-specific framework is of substantial relevance for PT designers looking to promote STEM enrolment among junior secondary school female learners in Nigeria. The PET4TSEM framework provides design considerations that are specific to junior secondary school female learners and STEM subjects in the Nigerian context. The components of the PET4STEM framework were theoretically and empirically supported and further evaluated by STEM experts in Nigeria.

8.4.2 Empirical Contribution

At an empirical level, the study establishes the factors that influence junior secondary school female learners' enrolment in STEM disciplines. There are limited studies that have empirically investigated the factors that affect the enrolment in STEM of female learners in junior secondary schools in Nigeria (Li et al., 2020). Most studies are focused on countries in the West and Asia. The few studies that are aimed at the Nigerian audience are focused on young women in senior secondary schools and universities (Ugwuanyi et al., 2020). Meanwhile, in Nigeria, students choose their academic path in the final year of junior secondary school (Federal Ministry of Education Nigeria, 2019), so females in senior secondary schools and universities have already decided on a career path. This makes targeting students in junior secondary schools is imperative. Hence, empirical data from this cohort of audience can serve as a solid foundation for future studies.

8.4.3 Practical Contribution

At a practical level, this study provides persuasive strategies that can be employed to mitigate the negative perceptions about STEM subjects that female students hold. These strategies can be used by schoolteachers, parents, and researchers who are not developing a PT tool. In addition, the study provides the teaching and learning approaches that can be employed to change the attitude of female learners towards STEM professions. These approaches can also be used by schoolteachers in class or parents at home who are not developing PT tools. Thirdly, the study provides the technologies that can accommodate the delivery of STEM instructional content to promote STEM class enrolment among junior secondary school female learners. PT designers or researchers who are developing PT tools can use this information. Lasty, the PET tool can be used by schools and parents looking to change the perception of their female children about STEM subjects and disciplines.

8.5 LIMITATIONS AND FUTURE WORK

This study, like all research studies, has limitations. The researcher acknowledges that the number of female students and STEM teachers interviewed for developing the PET4STEM framework could have been more. However, the rationale behind not gathering many participants is that the study is focused on gaining deep insights into the phenomenon under study, thus, a small number of information-rich participants that can illuminate the phenomenon under study were recruited and they provided the needed information. This is typical of qualitative research works where the focus is on conceptualizing an idea so that it can be further explored by similar cases rather than generalizing what was found (Polit & Beck, 2010). Despite this argument, a potential future work is to collect quantitative data from a larger number of participants in addition to qualitative data so that the findings can be generalized.

The STEM teachers interviewed for developing the PET4STEM framework were all males. The researcher could have searched for a STEM teacher even if it is from a different school from the students. Another limitation of the study is that the social facilitation strategy was selected twice for easy implementation, despite that it was implemented differently for the different barriers, the researcher agrees that using at least two different persuasive strategies might have increased features in the tool. A potential future work is to use a variety of strategies.

Also, the researcher admits that the interview questions for evaluating the PET4STEM tool should have been worded in a way that the desired outcome would not be contained within the wording of the question. This was unintentional and the researcher admits that with such questions there is a risk of social desirability bias.

A further weakness of this research is that the students used the developed PET tool for three weeks to test its effectiveness. Based on the literature reviewed in Chapter 2 of this study, such short periods are not sufficient for learners to build a long-lasting and meaningful relationship with STEM subjects. Learners need to be continuously engaged over a long period so that they develop relationships with peers, mentors, and the STEM community and build permanent and meaningful relationships with STEM (Prieto-Rodriguez et al., 2020). Hence, as future work, a longer period, at least one year, would be dedicated to testing a fully developed PET tool.

8.6 RECOMMENDATION

This section provides the practical and theoretical recommendations of the study.

8.6.1. Recommendations for Practical.

The researcher recommends that designers following the PET4STEM framework should strive to develop a full-scale PET tool and not a pilot tool as was done in this study. This is to ensure that the full potential of the framework is utilized. Furthermore, the number of PET personnel used in a full-scaled PET tool should be at least one-third of the number of students, with one personnel for every three students. This ensures that each student receives the attention they require. Additionally, it is recommended that PET designers view the framework as an idea to build on not a strict rule to follow. In other words, they should include their imagination in the design. This was suggested by some experts who were interviewed. Lastly, secondary schools in Nigeria should consider having a PET tool that their students can access to help counter the effect of environmental and individual factors that may affect their enrolment into STEM pathways.

8.6.2 Recommendation for Theory.

Despite the positive feedback from the participants of this study regarding the PET tool, the researcher recommends that newer persuasive strategies that are well tailored to this digital age should be developed. Also, more engaging and innovative pedagogies that can incorporate in today's technologies should be developed to accommodate the dynamics of this digital era.

8.7 CONCLUSION

This research aimed to develop a PET-based framework that guides the design of PET tools that would be used to motivate junior secondary school female students in Nigeria to enrol in STEM pathways. If the research had gone with the proliferation of literature pointing to some individual-level factors, for instance, self-efficacy, as the single most important factor preventing young female learners from choosing stem pathways, the researcher would have perceived that the students need to be motivated to overcome their phobia for STEM subjects. Instead, the in-depth questions and conversations with the female learners, STEM teachers, and STEM experts helped uncover the true reasons for junior secondary school female learners' professional choices, and as a result, appropriate and relevant information regarding how to motivate female learners to enrol in STEM were provided in this study.

Specifically, it was deduced that young Nigerian female learners want their thoughts and actions to be consistent, hence, they choose professions that resonate with their identity within their society. They recognize that society views them to be more interpersonal and inherently caring than their male counterparts so they channel their interest to professions in the arts and humanities where they feel they can help care for people and make people happy.

With this knowledge, the researcher was able to suggest support that would reinforce and sustain female learners' interest in STEM professions while remaining true to their sociocultural identity, norms, and values. Specifically, it was realized that four main pieces of knowledge are imperative to designing a PET tool aimed at motivating junior secondary school female students in Nigeria to enrol in STEM pathways. These pieces of knowledge are:

I. The knowledge of the barriers to enrolling in STEM pathways: Designers must be aware of the barriers that hinder female students' enrolment into STEM disciplines. This is because very little can be accomplished concerning solving a problem if the causes of the problem are not first identified.

II. Persuasive knowledge: Designers must be informed of the persuasive strategies that young females in Nigeria are more susceptible to. This is because what motivates one individual may not motivate another and what motivates in one domain may not motivate in another.

III. Pedagogical knowledge: Designers must know of the teaching and learning approaches that can accommodate the persuasive strategies and are suited to teaching STEM subjects. This is because the curriculum, learning objectives, ways in which instructional contents are sequenced, and how ideas are interconnected differ for every discipline.

IV. Technology knowledge: Designers must know the technologies that can accommodate the teaching and learning strategies for the effective delivery of the instructional content. The technologies should also be those that female students will embrace, those that will accommodate, and those that persuasion communications can be integrated into.

In conclusion, despite the limitations of the study, the researcher is confident that the findings of the study will contribute to developing PET tools for motivating junior secondary school female learners to enrol in STEM pathways when they transition to senior secondary classes in Nigeria.

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APPENDICES
Appendix A

Request for permission to conduct interview with student on a research titled:
A DESIGN SCIENCE RESEARCH FRAMEWORK FOR A PERSUASIVE EDUCATIONAL TECHNOLOGY-BASED TOOL FOR MOTIVATING JUNIOR SECONDARY SCHOOL FEMALE STUDENTS IN NIGERIA TO ENROL INTO STEM.

Dear principal,

I, Aisha Muhammad Abdullahi am doing research with Bester Chimbo an Associate Professor in the Department of Information Systems towards a PhD at the University of South Africa. We are inviting you to participate in a study entitled “A Design Science Research Framework for A Persuasive Educational Technology-Based Tool for Motivating Junior Secondary School Female Students in Nigeria to Enrol into STEM”.

The aim of the study is to design a persuasive educational technology framework for motivating junior secondary school girls to enrol in STEM disciplines when they transit to senior secondary class.
Your school has been selected because it has the audience that this study is targeted at.

The study will entail:
Participating in interviews and focus group sessions. The students will be asked questions regarding factors that influence their decision to enrol in STEM disciplines. The questions will revolve around family factors, school factors, sociocultural factors, and individual factors that influence their decision to enrol in STEM disciplines.

Their responses will be discussed with STEM professionals and STEM teachers to get their opinion on why female students choose non-STEM careers over STEM careers. They will not be identified by their responses as no identifiable information will be collected from them. They will be interviewed again after the opinions of the professionals and teachers to find out if they agree with what they opine. Each interview session will take approximately 20 minutes so that they can comfortably express their views. The information gotten from them, the STEM professionals and teachers will be used to inform the study.

STEM learning objectives are aimed at nurturing students to become lifelong learners, critical thinkers, and problem-solvers. Hence, when girls take STEM subjects it may improve their confidence and consequently their potential to contribute to societal growth and development.

Potential risks are: There is no foreseeable risk of involvement in the study.

Feedback procedure will entail contacting Aisha Muhammad Abdullahi, 67079229@mylife.unisa.ac.za, +2347020291932. Should you have concerns about the way in which the research has been conducted, you may contact Prof. Bester Chimbo, Associate Professor, Department of Information Systems, +2711 670 9105, chimbb@unisa.ac.za. Contact the research ethics chairperson of the Unisa School of Computing Ethics Review Committee (ERC), SocEthics@unisa.ac.za if you have any ethical concerns. Please do not use home telephone numbers. Departmental and/or mobile phone numbers are acceptable.

Yours sincerely

Aisha Muhammad Abdullahi

PhD Student at Unisa

Appendix B

LEARNER’S ASSENT TO PARTICIPATE IN THIS STUDY

A Design Science Research Framework for A Persuasive Educational Technology-Based Tool for Motivating Junior Secondary School Female Students in Nigeria to Enrol into STEM”.

Dear __student__ Date _13/03/2022_

I am doing a study on A Design Science Research Framework for A Persuasive Educational Technology-Based Tool for Motivating Junior Secondary School Female Students in Nigeria to Enrol into STEM”.as part of my studies at the University of South Africa. Your principal has given me permission to do this study in your school. I would like to invite you to be a very special part of my study. I am doing this study so that I can find how to motivate you to enrol in STEM class when you transition to senior secondary school. This may help you and many other learners of your age in different schools.

This letter is to explain to you what I would like you to do. There may be some words you do not know in this letter. You may ask me or any other adult to explain any of these words that you do not know or understand. You may take a copy of this letter home to think about my invitation and talk to your parents about this before you decide if you want to be in this study.

The study involves interviews and focus group sessions. You will be asked questions regarding factors that influence your decision to enrol in STEM disciplines. The questions will revolve around family factors, school factors, sociocultural factors, and individual factors that influence your decision to enrol in STEM disciplines. Your responses will be discussed with STEM professionals and STEM teachers to get their opinion on why female students choose non-STEM careers over STEM careers. You will not be identified by your responses as no identifiable information will be collected from you. You will be interviewed again after we get the opinions of the professionals and teachers to find out if you agree with what they opine. Each interview session will take approximately 20 minutes so that you can comfortably express your views. The information gotten from you, the STEM professionals and teachers will be used to inform the study.

I will write a report on the study, but I will not use your name in the report or say anything that will let other people know who you are. Participation is voluntary and you do not have to be part of this study if you don’t want to take part. If you choose to be in the study, you may stop taking part at any time without penalty. You may tell me if you do not wish to answer any of my interview questions. No one will blame or criticise you. When I am finished with my study, I shall return to your school to give a short talk about some of the helpful and interesting things I found out in my study. I shall invite you to come and listen to my talk.

Having more females in STEM will help increase the number of STEM skill we have in Nigeria. In addition, STEM learning objectives are aimed at nurturing students to become lifelong learners, critical thinkers, and problem-solvers. Hence, when girls take STEM subjects it may improve their confidence and consequently their potential to contribute to societal growth and development.

Potential risks are: There is no foreseeable risk of involvement in the study.

You will not be reimbursed or receive any incentives for your participation in the research.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about this study, you can talk to me or you can have your parent or another adult call me at +2347020291932Do not sign the form until you have all your questions answered and understand what I would like you to do.

Researcher: _Aisha Muhammad Abdullahi__ Phone number: __+2347020291932 __

Do not sign the written assent form if you have any questions. Ask your questions first and ensure that someone answers those questions.

WRITTEN ASSENT

I have read this letter, which asks me to be part of a study at my school. I have understood the information about my study and I know what I will be asked to do. I am willing to be in the study.

Learner's name (print): Learner's signature: Date:

Witness's name (print) Witness's signature Date:

(The witness is over 18 years old and present when signed.)

Parent/guardian's name (print) Parent/guardian's signature: Date:

Researcher's name (print) Researcher's signature: Date:

Appendix C

PARENTAL CONSENT TO PARTICIPATE IN THIS STUDY

Dear Parent

Your ward/child is invited to participate in a study entitled A Design Science Research Framework for A Persuasive Educational Technology-Based Tool for Motivating Junior Secondary School Female Students in Nigeria to Enrol into STEM.

I am undertaking this study as part of my doctoral research at the University of South Africa. The purpose of the study is to design a persuasive educational technology framework for motivating junior secondary school girls to enrol in STEM disciplines when they transit to senior secondary class. The possible benefit of the study is that when girls take STEM subjects the number of STEM skill in the country will increase. In addition, STEM education may improve their confidence and consequently their potential to contribute to societal growth and development. I am asking permission to include your child in this study because be this study targets female students in junior secondary classes one to three (JSSI-JSSIII) which your ward/child fall into I expect to have 14 other respondents in the study.

If you allow your child to participate, I shall request him/her to partake in interviews and focus group sessions.

Your child will be asked questions regarding factors that influence their decision to enrol in STEM disciplines. The questions will revolve around family factors, school factors, sociocultural factors, and individual factors that influence their decision to enrol in STEM disciplines. Their responses will be discussed with STEM professionals and STEM teachers to get their opinion on why female students choose non-STEM careers over STEM careers. They will not be identified by their responses as no identifiable information will be collected from them. They will be interviewed again after we get the opinions of the professionals and teachers to find out if they agree with what they opine. Each interview session will take approximately 20 minutes so that they can comfortably express their views. The information gotten from them, the STEM professionals and teachers will be used to inform the study.

His/her responses will not be linked to his/her name or your name or the school's name in any written or verbal report based on this study. Such a report will be used for research purposes only.

There are no foreseeable risks to your ward/child by participating in the study. Your ward/child will receive no direct benefit from participating in the study; however, the possible benefits to education is that it will inform the research design society on how to design educational apps to motivate junior secondary school girls to enrol in STEM class when they transition to senior secondar class. Neither your child nor you will receive any type of payment for participating in this study.

Your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusal to participate will not affect him/her in any way. Similarly, you can agree to allow your child to be in the study now and change your mind later without any penalty.

Your ward/child may use the educational app anytime during their free hours.

In addition to your permission, your child must also agree to participate in the study you and your child will also be asked to sign the assent form which accompanies this letter. If your child does not wish to participate in the study, he or she will not be included and there will be no penalty. The information gathered from the study and your child's participation in the study will be stored securely on a password-protected computer in my locked office for five years after the study. Thereafter, records will be erased.

STEM learning objectives are aimed at nurturing students to become lifelong learners, critical thinkers, and problem-solvers. Hence, when girls take STEM subjects it may improve their confidence and consequently their potential to contribute to societal growth and development.

Potential risks are: There is no foreseeable risk of involvement in the study.

There will be no reimbursement or any incentives for participation in the research.

If you have questions about this study please ask me or my study supervisors, Prof. Bester Chimbo, Associate professor, Department of Information Systems, +2711 670 9105, chimbb@unisa.ac.za. Permission for the study has already been given by ethics chairperson and the Ethics Research Committee of the School of Computing Ethics Review Committee (ERC), UNISA.

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the study. You may keep a copy of this letter.

Name of child: ____

Sincerely

_________________________ ___________________________ ________________

Parent/guardian's name (print) Parent/guardian's signature Date

_Aisha Muhammad Abdullahi____ _____ _________ ____12/03/2022____

Researcher's name (print) Researcher's signature Date:

Appendix D

PARTICIPANT INFORMATION SHEET

15/03/2022

A DESIGN SCIENCE RESEARCH FRAMEWORK FOR A PERSUASIVE EDUCATIONAL TECHNOLOGY-BASED TOOL FOR MOTIVATING JUNIOR SECONDARY SCHOOL FEMALE STUDENTS IN NIGERIA TO ENROL INTO STEM.

Dear Prospective Participant

I, Aisha Muhammad Abdullahi am doing research with Bester Chimbo an associate professor in the Department of Information Systems towards a PhD at the University of South Africa. We are inviting you to participate in a study entitled “A design science research framework for a persuasive educational technology-based tool for motivating junior secondary school female students in Nigeria to enrol into (Science, Technology, Engineering, and Mathematics) STEM.

WHAT IS THE PURPOSE OF THE STUDY?

The aim of the study is to design a persuasive educational technology framework for motivating junior secondary school girls to enrol in STEM disciplines when they transit to senior secondary class.

WHY AM I INVITED TO PARTICIPATE?

You have been chosen because this study targets female students in junior secondary classes one to three (JSSI-JSSIII) which you fall into. We have chosen this class group because this stage is very important for career motivation. It is the class group where students decide to choose their career path. Your name will not be recorded in any reports or publications, and no one will be able to connect you to the answers you give in any published records and your response will not be shared with your teachers nor will it affect your grades in any subjects. A total of 15 students will participate in this study.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

The study involves interviews and focus group sessions. You will be asked questions regarding factors that influence your decision to enrol in STEM disciplines. The questions will revolve around family factors, school factors, sociocultural factors, and individual factors that influence your decision to enrol in STEM disciplines. Your responses will be discussed with STEM professionals and STEM teachers to get their opinion on why female students choose non-STEM careers over STEM careers. You will not be identified by your responses as no identifiable information will be collected from you. You will be interviewed again after we get the opinions of the professionals and teachers to find out if you agree with what they opine. Each interview session will take approximately 20 minutes so that you can comfortably express your views. The information gotten from you, the STEM professionals and teachers will be used to inform the study.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

This study will not offer any incentive to its participant.

ARE THEIR ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

There is no foreseeable risk of involvement in the study.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

Your name will not be recorded anywhere, and no one will be able to connect you to the answers you give. Your answers will be given a code number, or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report.

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

The notes taken will be stored in electronic format and password protected in a computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. Hard copies will be shredded, and electronic copies will be permanently deleted from the hard drive of the computer using a relevant software program.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

This study will not offer any payment to its participant.

HAS THE STUDY RECEIVED ETHICS APPROVAL?

This study has received written approval from the Research Ethics Review Committee of the School of Computing, Unisa. A copy of the approval letter can be obtained from the researcher if you so wish.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to be informed of the final research findings, please contact Aisha Muhammad Abdullahi on +2347020291932 or 67079229@mylife.unisa.ac.za, am.abddullahi@fud.edu.ng. Please do not use home telephone numbers. Departmental and/or mobile phone numbers are acceptable. Should you require any further information or want to contact the researcher about any aspect of this study, please contact Aisha Muhammad Abdullahi on +2347020291932 or 67079229@mylife.unisa.ac.za, or am.abddullahi@fud.edu.ng.

Should you have concerns about the way in which the research has been conducted, you may contact Prof. Bester Chimbo, Associate professor, Department of Information Systems, +2711 670 9105, chimbb@unisa.ac.za. Contact the research ethics chairperson of Unisa School of Computing Ethics Review Committee (ERC), SocEthics@unisa.ac.za if you have any ethical concerns.

Thank you for taking time to read this information sheet and for participating in this study.

Thank you.

Aisha Muhammad Abdullahi

PhD student at Unisa

Appendix E

Interview Questions for the Female Students (These questions may be rephrased while interviewing the students for their. This is because the respondents are females between 11 and 18 years)

This survey investigates the factors that influence your decision to enrol in STEM subject when you transition to senior secondary school. From your responses we will also identify your susceptibility(responsiveness) to the various persuasive strategies (motivational strategies) that can be used to promote your enrolment n STEM.

- ***This is NOT a test; we only want to know what you think.***
- ***There are no right or wrong answers.***
- ***The interview will take approximately 20 minutes to complete.***

How old are you?

What class are you in?

Have you decided on whether you will be taking a STEM path or a non-STEM path, or you haven't decided yet?

Why are you choosing a STEM/non-STEM path?

What do you think has influenced your decision to choose a STEM path?

Probing questions on Parental factors

Parental education:

What is the educational level of your parents: mother?

father?

Parental career:

What is the occupation of your mother?

father?

How long has each one been in this profession: mother?

father?

What is their current level/rank: mother?

father?

Do they tell you about the positive/negative aspects of their jobs: mother?

father?

Parental religion:

What religion is your mother?

father?

Do you feel that your parents prefer a certain career/job type for you because of their religious beliefs: mother?

father?

Parental influence:

Do your parents have expectations for you regarding a career path: mother?

father?

Do you feel this expectation influenced your choice?

Do your parents take you to attend extracurricular STEM activities: mother?

father?

Do you feel that this kind of exposure influenced your choice?

Do you feel that your parents are supportive of your STEM education: mother?

father?

What do you think your parents can do to (further)promote your interest and engagement in STEM?

Probing questions on School factors

Personal attitude towards school

What motivates you to go to school?

What goals do you have with your education?

When sitting in a STEM class do you feel you are in a class that is for males? Why?

What builds your interest to engage with and learn more about a subject?

Is it important to you to know what other students are learning?

Do you adapt your behaviour quickly to the model of other students?

Is it important to you what other students think of what you are learning?

Is it important to you to know what academic choices other students are making?

Is it important to you what other students think of what academic choices you are making?

Influence of teachers

Do your STEM teachers behave in a certain way that makes you feel a STEM path is for boys while a non-STEM path is for girls?

What can your teachers do to motivate you to build interest in and enrol in a STEM path?

Influence of school

Do you feel your school is supportive of your goals?

Does your school have STEM clubs or partake in extracellular STEM activities like programming boot camps?

Do you think your school is supportive of your STEM education?

Does your school organize STEM competitions to test your knowledge on a subject?

-would that motivate you to engage with and learn more about the subject?

Does your school give prizes to girls who do well in a subject?

-would that motivate you to do well in that subject?

Does your school rank students based on grades in a subject?

-would that motivate you to engage with and learn more about the subject?

Probing questions on Individual factors

Perceptions about studying STEM

Do you feel that STEM disciplines are difficult? Why or why not?

Do you fear that with STEM subjects you will encounter some problems in class that will be so difficult you will not be able to solve them?

Do you feel clever enough to study any of the STEM subjects in senior secondary class?

Would you feel confident answering questions during STEM lessons in class?

Perceptions about working in STEM

What do you think about the idea of STEM disciplines being for males?

Why do you think there are fewer females in STEM than males?

Which one do you think is more important for success in a STEM discipline: intelligence or hard work?

What is your opinion about a job that involves interacting with people?

What is your opinion about a job that involves interacting with things, like machines, gadgets, tools etc.?

Would you describe STEM jobs as being more people-oriented or things-oriented?

Long-term career goals

Do you wish to become wealthy or would you be contented with just being financially comfortable?

Do you wish to become well-known among peers in your profession or would you be happy to just get your work done and have self-esteem?

Probing questions on Sociocultural factors

Perceived responsibility to family

Do you feel you have a responsibility to support your family when you grow up?

How do you feel you can be of help or support to your family?

Perceived responsibility to society

Do you feel the need to give back to your society?

How do you feel you can contribute to your community/society?

What do you think you can achieve from a non-STEM/STEM career that can help you contribute to your community/society?

How do you think you will be able to use those achievements to contribute to your community/society?

Societal influences on choice of career

Do you think women are allowed to be as ambitious as men in your community?

Are there certain job roles that your society prefers females to take?

Are you aware of any norms or values that women are expected to conform to in your community/society?

Have these norms or values influenced your choice of career?

Which factor motivates you more in choosing a future career: the financial benefits of the job or the social relevance of the job to your society?

Does the prospect of being more respected and valued because you work in certain careers influence your choice?

Interview Questions Interview Questions for the STEM teachers.

This survey investigates the factors that influence female student's decision to enrol in STEM subject when you transition to senior secondary school. From your experience, we you're your view on this.

- ***The interview will take approximately 20 minutes to complete.***

Do you think that there is a gender gap in STEM fields?

What do you think are the females' motivations to take non-STEM careers over STEM careers?

Do you think there are family-related factors that influence females' decision to enrol in STEM disciplines?

Probe: What are the family factors?

Do you think there are school-related factors that influence females' decision to enrol in STEM disciplines?

Probe: What are the school factors?

Do you think there are sociocultural factors that influence females' decision to enrol in STEM disciplines?

Probe: What are the sociocultural factors?

Do you think there are individual-related factors that influence females' decision to enrol in STEM disciplines?

Probe: What are the individual factors?

Do you think that females go into STEM for the same reasons as males?

For females that choose STEM paths, what do you think motivates them to do so?

From your experience, do you think girls have low self-efficacy for STEM subjects?

Do you think schools are supportive of female students' STEM education?

What can schools do to promote their interest and engagement in STEM?

As a STEM teacher, what do you think educators can do to encourage more female students to take up STEM paths?

The researcher will then discuss the interview responses of the student with the STEM teacher to see if they agree with their responses.

Interview Questions Interview Questions for the STEM professionals

This survey investigates the factors that influence female students' decision to enrol in STEM subject when you transition to senior secondary school. From your experience, we you're your view on this.

- ***The interview will take approximately 20 minutes to complete.***

Do you think that there is a gender gap in STEM fields?

What do you think are the females' motivations to take non-STEM careers over STEM careers?

Do you think there are family-related factors that influence females' decision to enrol in STEM disciplines?

Probe: What are the family factors?

Do you think there are school-related factors that influence females' decision to enrol in STEM disciplines?

Probe: What are the school factors?

Do you think there are sociocultural factors that influence females' decision to enrol in STEM disciplines?

Probe: What are the sociocultural factors?

Do you think there are individual-related factors that influence females' decision to enrol in STEM disciplines?

Probe: What are the individual factors?

Do you think that females go into STEM for the same reasons as females?

For females that choose STEM paths, what do you think motivates them to do so?

From your experience, do you think girls have low self-efficacy for STEM subjects?

Do you think that STEM personnel have been contributing to closing the gender gap in STEM education?

As STEM personnel, what do you think your organization can do to encourage more female students to take up STEM paths?

The researcher will then discuss the interview responses of the student with the STEM personnel to see if they agree with their responses.

Appendix F

Interview Questions for the Female Students Regarding the PET tool (These questions may be rephrased while interviewing the students. This is because the respondents are females between 11 and 18 years)

Interview question 1. What would you say about the platform, does it help you realize that there are female STEM teachers in Nigeria and around the world?

Interview question 2. How do you feel about STEM professions knowing that there are female STEM teachers in Nigeria and around the world?

Interview question 3. How do you feel having a female STEM teacher answer your questions, does it make any difference to your learning and engaging with STEM subjects?

Interview question 4. In the platform, you had to engage with the other students and STEM teachers. How do you feel having these options, do they make any difference to your learning and engaging with STEM subjects?

Interview question 5. You had activities with open-ended questions in which you had to explore different solutions before arriving at a reasoned answer, what do you think about such learning activities?

Interview question 6. There is a chat feature on the platform through which you interact directly with other students and STEM personnel, what is your opinion about this feature with regards to making the platform interactive?

Interview question 7. There is a blog feature on the platform through which you view and gain access to links on STEM career and mentorship programs. Did you access any of these programs, if yes, what is your opinion about this feature with regards to it helping you gain access to platforms where you can clear your misconceptions about STEM professions?

Interview question 8. There are links to institutions that offer scholarship opportunities to female students, did knowing about these scholarship programmes help you realize that STEM fields are not just for men?

Interview question 9. If you are given the chance to use the platform again, what would you like to be added or removed from the platform?

Interview question 10. Overall, were you comfortable using the platform and was using the platform enjoyable to you?

Appendix G

UNISA university of south africa

UNISA COLLEGE OF SCIENCE, ENGINEERING AND TECHNOLOGY'S (CSET) ETHICS REVIEW COMMITTEE

2022/05/16

Dear Aisha Muhammad Abdullahi

ERC Reference #: 2022/CSET/SOC/013
Name: Aisha Muhammad Abdullahi

Student #:67079229
Staff #:

Decision: Ethics Approval from 2022/05/16 to 2027/05/16
Humans involved

Researcher(s): Aisha Muhammad Abdullahi
67079229@mylife.unisa.ac.sa, +2347020291932

Supervisor (s): Prof Bester Chimbo
chimbb@unisa.ac.za, 011 670 9105

Working title of research:

A Framework for Designing a Persuasive Educational Technology Tool for Motivating Junior Secondary School Female Students in Nigeria to Enrol into STEM: A Design Science Research Approach

Qualification: PhD in Information Systems

Thank you for the application for research ethics clearance by the Unisa College of Science, Engineering and Technology's (CSET) Ethics Review Committee for the above mentioned research. Ethics approval is granted for 5 years.

*The **low risk application** was expedited by the College of Science, Engineering and Technology's (CSET) Ethics Review Committee on 2022/05/16 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment. The decision will be tabled at the next Committee meeting for ratification.*

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

Appendix H

Approval Letter from First School

KANO STATE SENIOR SECONDARY SCHOOLS MANAGEMENT BOARD

GOVERNMENT SECONDARY SCHOOL, NAIBAWA

P.M.B. 3427, DAWAKIN KUDU ZONE

Our Ref:................ Your Ref:................ Date: 23/6/2022

Permission to Conduct Research at Government Secondary School Naibawa.

The Ethics Review Committee, Unisa School of Computing.

Aisha Muhammad Abdullahi has been granted permission to conduct a research study at Government Secondary School Naibawa on "A Design Science Research Framework for A Persuasive Educational Technology-Based Tool for Motivating Junior Secondary School Female Students in Nigeria to Enroll into STEM". The school authority is aware of the design of the study as well as the targeted population and supports this effort.

Please feel free to contact us at (+234) 8067644000 if you have any questions.

Sincerely,
Hashim Bala
For Principal Government Secondary School Naibawa.

Appendix I

Approval Letter from Second School

KANO

KANO CAPITAL SCHOOL

"YAN DUTSE ROAD
P.O. BOX 1058 TEL: 064-634708 KANO – NIGERIA

OUR REF:__________ YOUR REF: __________ DATE: 23rd June 2022

Dear Mrs. Abdullahi,

Re- Request for permission to conduct research at Kano Capital School.

We are happy to confirm to you that your request to research "A Design Science Research Framework for A Persuasive Educational Technology-Based Tool for Motivating Junior Secondary School Female Students in Nigeria to Enroll into STEM" at Kano Capital School has been granted. The school authority is aware that you will need to interview some students and teachers for the study and is happy to support this effort.

Sincerely,
Kabiru Zakari
For Principal Kano Capital School.

Appendix J

Approval Letter from Third School

KANO STATE SECONDARY SCHOOLS MANAGEMENT BOARD (KSSSMB)
مدرسة اللغة العربية للبنا ت زواروادكا نوا
GOVERNMENT GIRLS ARABIC SECONDARY SCHOOL ZOO ROAD
HOUSING ESTATE PHASE 1, KANO
MUNICIPAL ZONE
GSM: 08148610653

Our Ref: ________ Your Ref: ________ Date: June 21, 2022

Permission Letter to Conduct Research at Government Girls Arabic Secondary School Zoo Road.

Dear Unisa School of Computing Ethics Review Committee,

It is my understanding that Aisha Muhammad Abdullahi will be conducting a research study at Government Girls Arabic Secondary School Zoo Road on **A Design Science Research Framework for A Persuasive Educational Technology-Based Tool for Motivating Junior Secondary School Female Students in Nigeria to Enroll into STEM**. Mrs. Aisha Muhammad Abdullahi has informed me of the design of the study as well as the targeted population.

I support this effort and will provide any assistance necessary for the successful conduct of this study. If you have any questions, please do not hesitate to call. I can be reached at (+234) 7030196729.

Sincerely,
Lubabatu Aliyu Yola
Principal Government Girls Arabic Secondary School Zoo Road