A TRIARCHIC APPROACH TO INTEGRATING PHYSICAL SCIENCE CONCEPTS IN TEACHING AND LEARNING

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Abstract

This study investigates physical science teachers' approaches to concept integration in teaching and learning. If integration of concepts can be given a priority in teaching and learning, the performance of learners will improve enormously. A qualitative phenomenological design was employed in the study to understand participants' perceptions regarding the principle of integration. Phenomenology design helped the researchers to collect data from participants by listening to what they say (individual and focus group interviews) and also looking at what and how they do things (non-participant observation). A sample of eight teachers was purposively selected to participate in the study. Data was analysed thematically and supported with literature. The findings to this study revealed three themes, namely: understanding of the concept integration, the findings regarding the understanding of the concept integration reveal that participants lack a clear knowledge and understanding of the concept 'integration' as required by the National Curriculum Statement; the extent to which concepts have already been integrated, it was found that integration within and across the subjects such as physical science was not implemented and the challenges experienced when integrating concepts is from the lesson observations where there was no clear indication of a systematic lesson plan that serves as a guideline for teaching . The study suggests further research in the context of the principle of integrations.

Keywords: integration, integrated curriculum, curriculum integration, triarchic approach, revised national curriculum statement.

1.1 Introduction

It is assumed that most teachers in this province are still teaching subjects as individual units of learning. Teachers struggle to understand that concepts in various subjects could be linked together. For these reasons, learners enrolled for physical science in this province cannot achieve the expected results at the exit level of further education and training band (FET). There is limited research done on the phenomenon of physical science concepts integration in South Africa. In support of this view, a South African literature (Adler et al 2000) highlights the notion of the adoption of new pedagogical approaches to learning and teaching. The given literature states: "within the new South African context, little is known about how teachers work with the new pedagogical demands to integrate within and across the subjects" (Adler et al 2000:11). If the processes and procedures of the concept ‘integration’ can be well understood and effectively implemented in teaching and learning, both teachers and learners in the field of physical science will reap the benefit.

Teaching learners to become critical thinkers and to develop the skills necessary to excel in today’s society has become an important focus of education (Kaskey-Rough 2008). In South Africa, there are calls for schooling to shift from following structured curricula marked by a separation of the body of knowledge (Snyder 2000), to interdisciplinary curricula. The introduction of the new curriculum, the Revised National Curriculum Statement (RNCS) has placed demands on teachers to adopt integrated teaching approaches to their teaching practices (DoE 2003). The South African Department of Education views integration as a key design principle of the RNCS. Integration as a principle requires learners to use their knowledge and skills from other subjects as well as different parts of the same subject, in order to carry out the given tasks and activities (DoE 2003). For this reason, Adler et al (2000) describe integration as a key driving principle of the new South African curriculum.

This paper reports on an empirical study involving eight teachers teaching physical science from Grades 10 – 12 around Sekhukhune district in Limpopo Province, South Africa. The objective of the study was to find out if teachers are integrating physical science concepts within and across the subjects. However, the South African Department of Education (DoE 2003) emphasizes the principle of integration in teaching and learning, the population in this study still experiences some challenges in finding a way of implementing the principle of integration to its teaching practices.

1.2 Conceptualizing integration

The concept of integration is interpreted in many different ways (Davison et al 1995). The absence of uniform commonality in the interpretation of this concept has led to the unavailability of a common definition for integration (Mwakapenda and Dlamini 2010). Despite the unavailability of common definition for integration, it is discovered that integration itself is not a new literacy. There have been several attempts in South Africa and internationally to connect school physical science and other learning areas (Adler et al 2000).

According to the South African National Curriculum Statement for physical science (DoE 2003), integration is achieved within and across the subject in the field of learning and for this reason, the integration of knowledge and skills across the subjects and the terrains of practice are crucial for achieving applied confidence as defined in the National Qualification Framework (NQF). Applied competence aims at integrating discrete competences which include inter alia: practically, foundationally and reflective competence (DoE 2003). In adopting integration and applied competence the NCS Grades 10 -12 (General) seeks to promote an integrated learning of theory, practice and reflection (DoE 2003).

International literature (Furner and Kumar 2007) indicates that physical science and mathematics in schools have become a central issue by organisations such as the School Science and Mathematics Association (SSMA), the National Council of Teachers of Mathematics (NCTM), the American Association for Advancement of Science (AAAS) and the National Research Council (NRC). According to Furner and Kumar (2007) the integration of physical science and mathematics encompasses a number of considerations namely, mathematics as a language and tool for teaching physical science, or teaching physical science entirely as part of mathematics.

Davison et al (1995) identified five types of physical science and mathematics integration as follows: discipline specific integration; content; process; methodological and thematic. For discipline specific integration Davison et al (1995) refer to the activities that include two or more different branches of mathematics or physical science. Regarding content specific integration the authors state that it involves choosing an existing curriculum objective from mathematics and one from physical science. Methodological integration, Davison et al (1995) state that good science methodology should be integrated in good mathematical teaching. Process integration involves the scientific procedures such as conducting experiments, collecting data, analysing data and reporting the results. In the final type of integration, which is referred to as thematic integration, Davison et al(1995) indicate that thematic approach begins with a theme which then become medium with which all the disciplines interact. The study will focus on the thematic approach of integration.

Many science curricula stresses how physics, biology and earth sciences are integrated and have common concepts such as energy, energy transportation and conversation of energy. Despite all the compartmentalization in science, it can be argued that the different science disciplines have more in common than they have in difference (Bill 2007). In contrast, Satchwell and Leopp (2002) highlights the challenges of integrating concepts within science as follows: the education of science teacher provides one of the most significant roadblock of the implementation of high level of disciplinary teaching; few teachers have had an opportunity to experience true interdisciplinary lesson themselves as students; there is understandable resistance to change; and there are the pervasive external forces such as lack of planning time and pressure to perform with respect to pacing guides and end off course examination.

In light of the above explanation, this study centers on concepts such as integrated curriculum and curriculum integration. For the purpose of this study, these two concepts are used interchangeably. It is therefore imperative for one to outline and define the two concepts. The thematic approach will be used to address integration.

1.2.1 Integrated curriculum

Recent literature (Parker and Naidoo 2005; Paterson 2003; Kaskey-Rough 2008) defines and describes the concept 'integrated curriculum. For example, Parker and Naidoo (2005) defines integrated curriculum as a curriculum approach that purposefully draws together knowledge, perspective, and methods of inquiry from more than one discipline to develop a more powerful understanding of a central ideas, issue, person or event. In addition, Paterson (2003) see an integrated curriculum as a curriculum that brings together content from different disciplines in a meaningful way to focus upon issues and areas relevant to learner's lives. In an integrated curriculum there is an emphasis on higher-order thinking processes, cooperative learning, and thoughtful consideration of human values, rather than the minutiae of separate subjects (Kaskey-Rough 2008). These definitions suggest that using an integrated curriculum is an effective way to promote critical thinking in learners and also engage them in their learning.

It appears that there are benefits of using integrated curriculum in teaching and learning. To be precise, various authors (such as Shawn and Bill 2006; Frykholm and Glasson 2005; Koirala and Bowman 2003; Paterson 2003; Vars 2001; Adler et al 2000; Musslewhite 2000) outline the benefits of using integrated curriculum.

According to Shawn and Bill (2006) integration is done to promote collaboration, to reflect to the real world and connect an existing approach to school subjects. Based on this analysis, integrated curriculum provides opportunities for more relevant, less fragmented and more stimulating experiences for learners (Frykholm and Glasson 2005; Koirala and Bowman 2003). Paterson (2003) argues that an integrated curriculum is more rigorous and relevant than traditional approaches because it challenges young people to think, learn, and tackle issues that are important to them personally. In the same note, Vars (2001) highlights three proponents of an integrated curriculum: psychological; sociological; and philosophical. Vars (2001) further attest to why it is worth saving. He therefore describes the three proponents as follows (Vars 2001): in the first proponent 'psychological design', learners are highly motivated and learn better because an integrated curriculum relates to their needs, problems, concerns, interests, and aspirations. The second and the third proponents, who are respectively sociological and philosophical, show that learners in the proponents are better prepared for life in contemporary society because current social problems are addressed in all their real-life complexity. According to Vars (2001), learners in this context learn major concepts and processes of the disciplines through learning integrated units. An integrated curriculum supplies a sound foundation of common learning that is vital for all citizens in a democracy and provides a meaningful framework for examining values. Other benefits of implementing an integrated curriculum include: a love of learning, concern for other people, creative thinking, self-confidence and commitment to democratic group processes (Vars 2001).

While integration is desirable, the extent of the demand placed upon teachers make integration less feasible (Adler et al 2000). For teachers to integrate what they are teaching with other learning areas, teachers need not only have sufficient knowledge of their own areas, but they also need to have and be aware of a broad range of knowledge within and outside the curriculum (Mwakapenda and Dlamini 2010). Having an integrated curriculum will engage learners in real-world problem solving as they gain knowledge and skills (Musslewhite 2000), and for this reasons, the design will help learners to retain more of what they read, hear, say, and do, because they are given more opportunities to be active learners. Musslewhite (2000) further explains that a curriculum that crosses disciplines is a way to increase motivation, knowledge retention, critical thinking, and problem-solving skills.

1.2.2 Curriculum integration

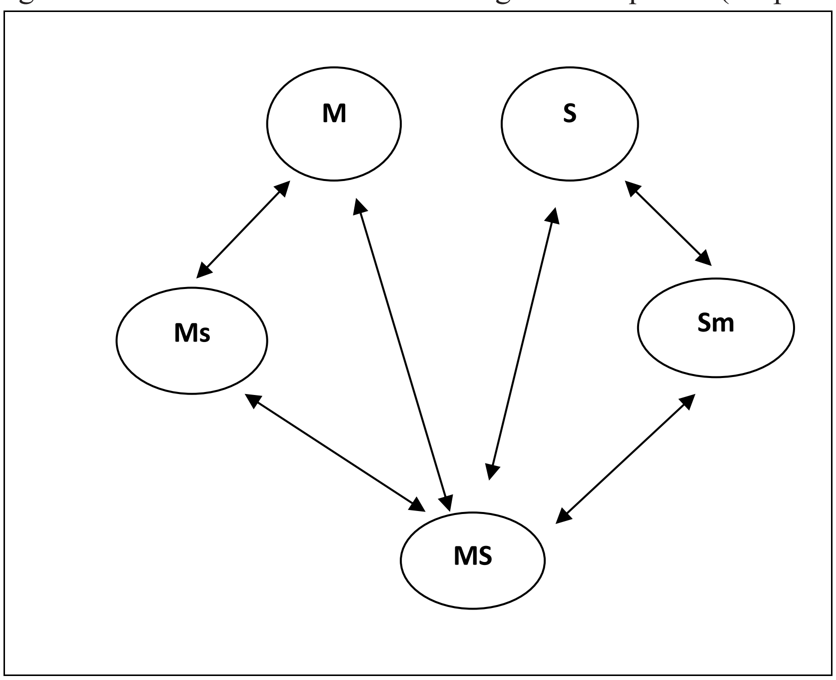
Curriculum integration is seen as something which is not simply a multidisciplinary approach to teaching and learning, but something that involves helping learners make connections across content areas, promoting democracy in the classroom by letting learners determine to a large extent what they want to learn (Paterson 2003). According to Paterson (2003), the purpose is not to eliminate the individual disciplines but to combine them. This simply means that curriculum integration purposefully draws together knowledge, skills, attitudes and values from within or across subjects to develop a more powerful understanding of the key ideas. However, teachers experience fewer disciplinary problems when using this design; they may also experience increased creativity in collaborating with others in nontraditional academic combinations (Burton 2001).

There are two clear benefits of curriculum integration which Hutchings (2006) see as that of the fostering of community and relationships. In this context, the teacher is no longer an information giver, but a facilitator of learning (Hutchings 2006). In view of the South African Department of Education (DoE 2003) teachers should be the mediators of learning, interpreters, and designers of learning programme and materials; leaders, administrators and managers; scholars, researchers and lifelong community members; assessors and specialists.

1.3 Theoretical Aspects

The study from which this paper emerged was guided by a framework of continuum model of integration. Lonning and Defranco (1997) designed a continuum model of integration that will assist teachers to clarify the relationship between concepts. The model focuses on the issue that different forms and degrees of integration are needed for successful delivery of the many types of concepts inherent in physical science and mathematics. The continuum of integrated curriculum model consists of continuous categories that present the different possibilities regarding the extent of interaction between content disciplines (Huntley 1998). The model shows how a teacher explicitly assimilates concepts from more than one discipline during instruction. The model further indicates five continuous categories that depict the different ways in which physical science and mathematics are interrelated (see figure 1). These categories include: mathematics for the sake of mathematics (M); mathematics with science (Ms), mathematics and science (MS); science with mathematics (Sm); and science for the sake of science (S). A simple representation of this continuum, with a capital letter denotes the primary emphasis and the lower case letter represents the secondary focus. To give a brief description of the continuum, at one end of the continuum would be mathematics activities not involving science, while on the other end of the continuum would be science activities not involving mathematics; at the center of the continuum are those activities meeting the curricular objectives for both science and mathematics then such activities can be referred to as balanced integrated activities. Finally, the model emphasises the importance of a team approach to theme selection and activity development.

Figure 1: Science and mathematics integration sequence (adapted from Huntley 1998)



Continuum model specifically addresses the levels of collaboration between teachers of different disciplines and the role learners play in the planning and delivery of classroom activities. Learners, teachers and teams of teachers collaborate not only across disciplines but also across Grade levels and other programmes offered in the school to study a topic. The teacher or team of teachers utilizes many content areas to examine a topic with a great amount of input from the learners in what problem will be studied and how the investigation of the problem will take place.

It could be suggested that teachers training institution may employ the continuum model in order to teach student teachers how to integrate physical science and mathematics as well as related content, skills, affective characteristics, teaching methods and approaches. Training teachers using this model may contribute to the common usage of integrated scientific and mathematical curriculum in National Curriculum Statement. This will yield better results of physical science in our country.

1.4 Study design and data collection

This study employed a qualitative phenomenological design. Phenomelogists are concerned with understanding social and psychological phenomena from the perspectives of people involved (Babbie and Mouton 2001; Rice and Eezy 1999; Welma and Kruger 1999). Based on the above explanation, the methods used to collect data in this study include interviews (individual and focus group) with the consent teachers as well as observing their lessons, because phenomenologist believes that multiple ways of interpreting experience are available to each of us through interaction with others (Bogdan and Biglen 2007). The study involved a sample of eight teachers purposively selected, from the participating schools around Sekhukhune district of Limpopo Province in South Africa. The rationale behind the purposive sampling was informed by the facts that all the participants were permanently appointed by the department of education to teach physical sciences from Grades 10 - 12. Due to their teaching experience, it is believed that these participants will provide rich data that will assist in answering the research problem. Eight participants were involved in the individual interviews. The same participants took part in a focus group interviews and were also observed when delivering the lessons. The purpose of using these methods was to explore the participant's understanding of the principle of integration, to find out the extent to which concepts have already been integrated to their teaching activities, and to investigate their challenges in integrating concepts to the teaching of subjects. Ethical considerations with regard to voluntary participation, anonymity and confidentiality were adhered to during data collection. Permission to conduct research in the schools was granted by the Limpopo Department of Education in South Africa. Permission was sought from teachers who were interviewed. Data was analysed qualitatively in terms of the themes and categories specified for the study. Although the findings of the study cannot be generalised owing to the small samples that were used, they provide rich information on teachers' perception on the integration of physical science to other disciplines. Interviews and observation were used in this study to come up with the findings that follow below.

1.5 Findings and discussions

The findings to this study are presented in line to the study objectives as described in the previous section.

Understanding of the concept 'integration'

The study shows that participants lack clear knowledge and understanding of the processes of integration as required by the South African Department of Education. In trying to explain what integration is, participants gave different interpretations of which some of them did not qualify integration as a principle of the RNCS. To be specific, one of the participants who seem to be well informed about the issues of integration states: *"well, integration is like when teaching physical science, we can't teach as simple subject. You must introduce some other concepts that are related to geography, mathematics and physical science. For example, when teaching transgression in mathematics, it will be integrated with physical science".* Another participant who seems not having a deeper understanding of the concept gave the following explanation: *"I think this is the combination of two or more things so that they can work together".* It is clear from the participants' views that there are different meanings attached to the understanding of the concept. This finding is in line with Mwakapenda and Dlamini (2010) who argue that the concept of integration is interpreted differently and the absence of common understanding in interpretation led to the unavailability of a common definition.

From the participant's perspective, in the process of integration, one or more subjects are involved. The subjects referred to in this discussion include geography, mathematics and physical science. However, the emphasis is more on physical science and mathematics, this explanation would suggest integration of concepts across the subjects. Pournara and Graven (2000) concur with these explanations and further identify three levels of integration, namely integration of various components of mathematics, integration between mathematics and everyday real world knowledge and integration across the learning areas.

Though some of the participants were able to explain their ideas regarding integration, this does not suggest that the implementation part of it has been successful. It is evident from the study that participants are still struggling to find the process right and for this reason, they have not yet implemented integration strategies to their teaching activities.

The extent to which integration has been used within and across the subjects

It is clear from the interviews that not all the participants have already integrated concepts within and across the subjects. From the focus group interviews participants explained that they have not yet integrated their concepts either within or across the subjects. Participants state: "*No…we did not integrate but we were just giving learners example or concepts and where in other subjects it appears and what does it mean. For example, when we talk of mixture in the classroom, must relate or associate with mixture at home that is their everyday life".*

Though the majority of participants still lag behind with issues of integration, some of the participants have good ideas of how integration is done. From the individual interviews, one participant who claimed to be integrating the concepts across different subjects put it clear when stating: *"there is no ways that I will teach physical science without integrating it with other subjects like mathematics. There are concepts that are related in both subjects, for example, in applied mathematics, you apply concepts that you have done in mathematics theoretically.*

Whereas the same concepts are dealt with practically in physical sciences".

In support of this notion, Batista and Matthews (2002) belief that science provides rich context and concrete phenomena demonstrating mathematics and mathematical patterns and relationships. At the same time mathematics provides the language and tools necessary for deeper analysis of science concepts and application. In the same note, Frykholm and Meyer (2002) contend that when scientific phenomena are pursued authentically, they can open the door for enriching exploration of mathematics concepts that otherwise would remain as isolated topic. Additionally, Vygotsky (2006) asserts that teaching science and mathematics separately has become extremely difficult due to enormous proliferation of content matter of each subject. He further states that integrated teaching of science and mathematics is likely to save time and vigor in learning those subjects. To become more precise, Vygotsky (2006) highlights that scientific ideas are best understood when they are presented in mathematics. For example, the mathematics form of conversion of matter into energy is the famous equation '$e=mc^2$. This simple energy equation shows how tremendous amount of energy is hidden in a small amount of matter. To Vygotsky, mathematical forms of science are brief but the information contained in such forms is quite huge and vast.

From the given explanation it seems participants look at integration with a single lens, a lens of integrating concepts across the subjects only. In actual fact, integration should not only be seen with a single lens, it must also be seen as an inner entity, i.e. within the subject itself.

Challenges to the integration of concepts

There are challenges experienced by participants with regard to the understanding of the principle of integration as stipulated in the curriculum. The challenges may result from the participants' difficulties in integrating physical science concepts within and across the subjects. From the lesson observations there was no clear indication of a systematic lesson plan that serves as a guideline for teaching. Participants were found to be using rough notes written down and followed when offering the lessons. Although there are samples of lesson plans stipulated in the prescribed books, it is evident from this study that participants do not follow the sample lesson plans. Lack of systematic plan affect the attainment of the set outcomes, both long and short term outcomes.

To attain the set outcomes, it is crucial to link the learning outcomes (LOs) with the assessment standards (ASs). In this regard, participants were challenged by this linkage, they could not consider the importance of the Los and the ASs of the subject taught. This suggests that there is no team work in planning the lessons in the schools as well as the entire cluster. Teachers work as individuals instead of working collaboratively as a team. The finding corroborates with Pickard et al (2006) who emphasise that teachers have to understand the importance of planning, collaborating with colleagues, reflecting on their planning and constantly review their plans in order to improve their instructional practice. Collaborative work does not affect teachers only, it also affect learners as they have to be responsible for their learning. For this reason, the NCS encourages learner-centred approach (DoE 2006) where learners work co-operatively towards the achievement of the set outcomes. According to Gravett (2001) co-operative learning, discussions, problem-solving and student research rest on the assumption that learning is an active process of constructing meaning and transforming understanding.

Training was highlighted in the study as one of the contributing challenge. From the individual interviews, participants indicated lack of training that would have enhanced them to drive the process of integration successfully. Though some participants indicate that they received training, these trainings were not properly done. For example, participants mentioned that some of the trainings were conducted for few hours after school and others were conducted for only few days. This obviously left the trainees in the dark spot as they were not satisfied with the outcomes of the training. One participant from the individual interviews explains: *"I cannot actually call this training, as we attended for only few hours after school. We were informed about NCS, whereas NCS needs more time and resources".*

Despite the insufficient time allocated for the trainings, it is pertinent from the individual interviews that trainers themselves were not knowledgeable about the subject content; they therefore followed a cascade model in meeting their goals. The cascade model itself has some weaknesses that also affect the success of the training. These weaknesses are highlighted by Jansen (1999) as follows:

- Many teachers who received training were not given sufficient time to train the staff backing at their schools.
- Because principals and heads of departments were generally not involved as trainers, the management of most schools did not provide the necessary support required to cascade the model at school level effectively.
- Many teachers who were trained by the district indicated that they felt confident to deliver sessions at their schools. However, when district staff visited schools to observe the training the rest of the staff were often disappointed at the poor quality of training that was presented.

1.6 Conclusion and recommendations

This study investigated if physical science teachers integrate concepts within and across the subjects. An understanding of the principle of integration as set in the RNCS will benefit practically everyone who is interested in educational matters. If teachers have to teach effectively, the principle of integration has to be followed. The findings of this study revealed that physical science teachers lack knowledge and understanding of concept integration as demanded by the South African Department of Education. Many teachers still experience a challenge in understanding the curriculum, and for this reason it is difficult for them to implement it correctly in the classroom activities.

It is from this study that the integration of concepts is highlighted in three subjects that are related. These include physical science, life sciences and mathematics. This would suggest a triarchic approach in linking the subjects together. The issue under discussion is that teaching subject in isolation will not assist learners to understand the concepts. For this reason the continuum model of integration shows some relevance to this study as it depicts a multi-directional sequence. It is therefore important that the physical science teacher, the mathematics teacher as well as the life science teacher work collaboratively to decide upon the appropriate sequence in the integrated learning environment so that the perspectives of all disciplines are fairly represented in a coherent and cohesive manner.

The study recommends that the principle of integration could only be implemented in teaching if the systematic guidelines can be put in place and followed. Teachers are familiar with the integration of concepts across the subjects, it is equally important that they also consider the integration of concepts within the subject. To attain these goals, proper training has to be put in place. It is noted in the study that the cascade model is not supported; therefore a model that will address the challenges to teacher training is necessary. Further research in this regard is suggested, so as to address the challenges experienced in the teaching and learning of physical science.

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