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Exploring the Influence of Science Teaching Orientations on Teacher Professional Knowledge Domains: A Case of Five Malawian Teachers

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Abstract
This paper explores the influence of Science Teaching Orientations (STOs) on Teacher Professional Knowledge (TPK) domains of five in-service Malawian secondary school science teachers. The study was grounded within Friedrichsten et al.'s (2011) definition of STOs and Gess-Newsome's (2015) conceptualization of TPK. We gathered data using semi-structured interviews on the two dimensions of STOs: goals and purposes of science teaching, and beliefs about science teaching and learning. We used a questionnaire to gather data on the third dimension—Nature of Science (NoS). To understand the influence of STOs on TPK domains, we used data that we collected through classroom observations. The classroom observations were analysed inductively then deductively against the STOs dimensions and TPK domains. Results show that the first two dimensions of STOs influenced some TPK domains. There was no influence of the NOS on TPK domains. Although the teachers had correct views about the NOS, the lack of influence between the NOS and TPK domains raises questions about their Pedagogical Content Knowledge (PCK) for the NOS. We discuss the implications of the findings on teacher education and in-service science teacher professional development.

Keywords: science teaching orientations, teacher professional knowledge, in-service teachers, nature of science, goals or purposes of science teaching

INTRODUCTION

One of the objectives of teaching science at secondary school level in Malawi is to inculcate various skills critical in the learning of science such as reasoning and problem-solving skills (Ministry of Education, Science and Technology, 2013). The chief examiner's reports on science, however, highlight that many students perform poorly in science (Malawi National Examinations Board, 2015). In the report, the argument is that poor Teacher Professional Knowledge (TPK) is a major contributing factor. TPK is defined as the overarching general knowledge of teaching that comes from research and practice. According to Gess-Newsome (2015) TPK is composed of five knowledge domains as shown in Table 1. This knowledge is tacit but manifests in the classroom through Pedagogical Content Knowledge (PCK) (Carlson & Daehler, 2019). While TPK is a knowledge base where teachers tap from when they are planning about teaching, PCK on the other hand is defined as "both a *knowledge base* used in planning and delivery of a topic in very specific classroom context and as a *skill* when involved in the act of teaching" (Gess-Newsome, 2015, pp 30-31). As such, PCK is central in that it helps teachers to transform the content knowledge into teachable units (Gess-Newsome et al., 2017; Shulman, 1987).

There have been efforts geared at curbing the problem of poor science student performance in Malawi. For example, the use of professional development courses to develop science teachers' professional knowledge and equip them with effective ways of teaching science (World Bank, 2010). Despite these efforts, the quality of teaching and students' performance on national examinations remain poor (Nampota, 2016). This demonstrates an unsustained use of knowledge gained from professional development programmes which Gess-Newsome (2015) attributes to

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Contribution to the literature

- The results reveal that in-service teachers have multiple goals or purposes of science teaching which influence the TPK domains in different ways during instruction.
- Although the teachers had correct views about NOS, the lack of influence between NOS and TPK domains raises questions about their Pedagogical Content Knowledge (PCK) for NOS.
- This study raises the issue of the need for curriculum framers to be explicit about the intention of the curriculum and their envisaged interpretations. This is coming in because of the probable effect the curriculum has on the lack of explicit influence of the third dimension of STOs – NOS on teachers' knowledge.

Table 1. Teacher professional knowledge domains

Knowledge Domain	Description	Sub-domains (coming from the description)
Assessment knowledge	Knowledge of both formative and summative assessment, including an understanding of what to assess, how to assess and reasons for those assessment practices.	What to assess Methods of assessment Reasons for assessment
Pedagogical Knowledge	This is the knowledge of instructional strategies and how they are differentiated according to the needs of students. It also includes classroom management strategies.	Classroom management Student engagement Instructional strategies
Content knowledge	"Teachers' raw, untransformed SMK" which includes: scientific processes, core ideas of the discipline, cross-cutting concepts, etc.	Practices for scientific knowledge generation Core ideas in science (principles, theories, facts, laws) Cross-cutting issues
Knowledge of students	Teachers' knowledge about students' experiences, their prior knowledge, learning abilities. This knowledge influence how teachers cater for students' needs.	Students' differences Pre-requisite knowledge Misconceptions
Curricular Knowledge	Includes teachers' knowledge about the goals of a curriculum, the structure of the curriculum, and the role of a scope and sequence of the curricular document.	Goals and objectives Scope and sequence of the curriculum Curriculum coherence Linkage to other topics

the Science Teaching Orientations (STOs) since they either filter or amplify the teachers' TPK displayed during the actual teaching.

The concept of STOs is defined differently in the literature (see Grossman, 1990; Magnusson et al., 1999). In this study, we used the Friedrichsen et al.'s (2011) position which defines STOs as a "set of interrelated beliefs having the following dimensions: goals and purposes of science teaching, views about the Nature of Science (NOS), and beliefs about science teaching and learning" (p. 372). According to Demirdöğen (2016), examining the relationship between STOs and TPK domains could be a window into gaining an understanding of the complex nature of beliefs and professional knowledge, that influence classroom practice and learner performance.

Although a few studies examine the influence of STOs on TPK and possible reasons for that, there is evidence that there is a link between teachers' beliefs and their professional knowledge. These few studies illuminate several key insights concerning STOs: STOs shape PCK (e.g., Magnusson et al., 1999), and teacher-centred STOs trigger poor quality instructions (e.g. Kind, 2016). Some of the studies that looked at the nature of the relationship between STOs and PCK were done with pre-service teachers (e.g., Aydin & Boz, 2013; Demirdöğen, 2016). However, most studies used Magnusson et al.'s (1999) categorisation of STOs despite its criticisms. This situation has left a gap in knowledge concerning the influence of STOs on TPK domains of in-service science teachers using Friedrichsen et al.'s (2011) categorization of STOs. Hence, the primary purpose of this study was to explore the influence of STOs on TPK domains. This study was guided by the following research question:

What evidence (if any) of influence do the in-service science teachers' STOs have on TPK domains?

SCIENCE TEACHING ORIENTATIONS

There are three dimensions of STOs as already highlighted above. The first dimension, goals and purposes of science teaching is explained by the construct of curriculum emphasis (Roberts, 1982, 2015). In his study, where he examined documents from the teaching and learning of science, such as textbooks and curriculum policy statements, Roberts (1982) realised that the documents had a set of messages that suggested why some topics and content were taught at a particular level of schooling. He identified seven curriculum emphases (everyday coping, structure of science, science, technology and society, scientific skills development, correct explanation, solid foundation, and self as explainer) and argued that they are a window into understanding the teaching and learning of science at particular levels. In this study, these curriculum emphases were taken as goals and purposes of science teaching – which is one of the dimensions of STOs (see Friedrichsen et al., 2011). This is because these curriculum emphases describe a coherent set of messages concerning the teaching and learning of science (Roberts, 2015). We describe these goals and purposes of science teaching in Appendix A. Studies that examined teachers' goals and purposes of science teaching using the curriculum emphasis framework include those of Demirdöğen (2016) in the Netherlands and Hansson et al. (2021) who looked at physics teachers' views about teaching physics in upper secondary school and used the curriculum emphasis concept to analyse their data as well as Maseko and Khoza (2021) who looked that the in-services' science teachers beliefs about goals and purposes of science teaching.

The second dimension of STOs is views about the NOS. Although NOS lacks a clear definition in the literature, Lederman (2007) argues that it "typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (p. 833). In this study, views about the NOS refer to how teachers perceive what science is and how science works. Views about the NOS can be categorised into naïve, transitional and informed (see Khishfe & Abd-El-Khalick, 2002; Lederman et al., 2002) against the basic tenets of the NOS (see, Khine, 2012). Naïve views about the NOS are those that demonstrate a misconception about any NOS aspect. Similarly, if a teacher's view about the NOS is correct but demonstrated a deficient explanation or failed to give an example from the history of science to justify the answer, it would be categorised as transitional. On the other hand, if the answer to the question is correct and accompanied by a justification, the response would be categorised as informed. Some empirical research has been done concerning the beliefs about the NOS. For example, Faikhamta (2013) looked at the extent to which a professional development course based on the NOS affected teachers' understanding of the NOS as well as their STOs related to the NOS. Before the course, a majority of the teachers held naïve views about the NOS, and after the professional development, teachers had developed an understanding of this dimension of STOs. In a study conducted by Demirdöğen and Uzuntiryaki-Kondakçı (2016), similar findings were obtained where teachers' understanding of the NOS developed after a professional development course. Furthermore, Erduran et al. (2020) found that pre-service teachers had informed knowledge of the NOS after participating in group discussions.

The third dimension, beliefs about science teaching and learning, touches on several aspects concerning the teaching and learning of science, especially during teacher lesson planning (such as the source of teachers' content when they are planning to teach) as well as teachers' delivery of content (such as the role of the teacher during instruction). Luft and Roehrig (2007) categorised these beliefs into five categories; traditional, instructive, transitional, responsive, and reform-based. The first two categories (traditional and instructive) are teacher-centred while the last two (responsive and reform-based) are student-focused while transitional signifies that the teachers' beliefs fall between teacher-centred and student-centred (see Appendix B). Beliefs about science teaching and learning are acknowledged in PCK research (see Davidowitz & Rollnick, 2011). While beliefs about teaching and learning of science are presented as a contextual factor in PCK studies. In this study, it is one of the critical dimensions of STOs.

TEACHER PROFESSIONAL KNOWLEDGE

Several TPK models have been proposed for school teachers (e.g., Gess-Newsome, 2015; Rollnick et al., 2008). The underlying assumption of these studies is that, apart from content knowledge, teachers are unique and, as a result, they are bound to have knowledge that distinguishes them from other professionals even if they received the same content knowledge. In this study, we defined TPK as any other teacher knowledge that is relevant in their teaching and learning process and has the following domains: content knowledge, pedagogical knowledge, knowledge about the learners, curricular knowledge, and assessment knowledge (Gess-Newsome, 2015). These knowledge domains allow teachers to effectively discharge their duties in the teaching and learning process. However, this knowledge is filtered or amplified by STOs before manifesting in the classroom. The five TPK domains and sub-domains are described in Table 1.

RESEARCH DESIGN AND METHODOLOGY

This was a qualitative study (Creswell, 2012) and we employed an exploratory case study design (Hancock, 2006) to explore the in-service science teachers' influence of STOs on TPK domains.

Participants and Context

Five in-service science teachers were purposively sampled from three different schools in Malawi (see Table 2). The participants were considered a case (Merriam & Merriam, 2009) by the fact that they annually take part in the professional development programme organised by the ministry of education.

Table 2. Context of the participants

School and teachers	Secondary school type	Description
School 1 (Teacher 1)	District boarding school	Has laboratories Has boarding facilities
School 2 (Teachers 4 and 5)	Community day school	Does not have labs No boarding facilities Double shift school
School 3 (Teachers 2 and 3)	District day school	Has laboratories No boarding facilities Double shift school

Table 3. Summary of lessons observed for all the teachers

Teacher	Lesson 1	Duration (minutes)	Lesson 2	Duration (minutes)	Form
T1	Energy	40	Electric current	80	1
T2	Specific heat capacity	30	Machines	60	2
T3	Magnetism	60	Electricity, magnetism and electric induction	60	4
T4	Pressure in liquids	30	Chemical reactions	30	3
T5	Electricity – electrical energy and power	30	Electricity – electromagnetic induction	30	4

As can be seen in Table 2, not all schools have laboratories. We envisaged that this could impact the teachers' beliefs and practices. Unlike community day schools which are mostly located in rural areas, district day schools are mainly located in town and hence, availability of laboratories.

Data Collection

Interviews

We gathered data using semi-structured interviews (Cohen et al., 2007) about the goals and purposes of science teaching and the beliefs about science teaching and learning. The interview schedules were drawn from Demirdöğen (2016), and Luft and Roehrig (2007) respectively. Before being used, both interview schedules were piloted with three teachers that did not form part of those that took part in this study. We conducted interviews with each of the five teachers. The interviews lasted between 60 minutes to 80 minutes.

Questionnaires

We used a questionnaire to gather data on the teachers' beliefs about the NOS. We developed the questionnaire from various NOS instruments in the literature: Views on Nature of Science Questionnaire Form C (VNOS-C, Lederman et al., 2002), Views of Scientific Inquiry (VOSI, Schwartz et al., 2008), and Views About Scientific Inquiry (VASI, Lederman et al., 2014). We only isolated those items aligned to the following; nature of scientific knowledge, scientific theories and laws, science and creativity, scientific method as well as social-cultural aspects of science which are the aspects that are emphasised by the science curriculum in Malawi. After piloting the questionnaire with three science teachers (not part of this study), the questionnaire was then distributed to the five participating teachers.

Classroom observations

The influence of STOs on TPK domains was mainly examined from classroom observations. We observed two lessons from each teacher that translated to ten lessons for all the teachers as shown in Table 3.

The observations were video-recorded by a research assistant and transcribed verbatim for analysis. The first author sat in the classrooms during observations to make field notes.

Data Analysis

Three data sets were collected; questionnaires, interviews, and classroom observations. We first analysed each data set separately before holistically analysing them to address our research question. We describe how each data set was analysed below.

Analysis of questionnaires

To analyse the questionnaires about teachers' beliefs about the NOS, we used a deductive approach (Patton, 2002) employing a categorisation scheme that is widely used in the NOS studies (Kishfe & Abd-El-Khalick, 2002; Lederman et al., 2002). The three categories of the NOS are; naïve, transitional and informed (see Khishfe & Abd-El-Khalick, 2002). A teacher's view about the NOS was categorised as naïve if it demonstrated a misconception or the explanation regarding the NOS aspect was incorrect. Similarly, if a teacher's view about the NOS was correct but demonstrated a deficient explanation or failed to give an example from the history of science to justify the answer, we categorised it as transitional. We categorised a response as informed if the answer to the question was correct and if the teacher gave a suitable example from the history of science to justify the answer.

Analysis of interviews

The interview transcripts we coded deductively to get an understanding of the two dimensions of the STOs; goals and purposes of science teaching, and teachers' beliefs about science teaching and learning. Questions that pointed to the goals and purposes of science teaching in the interview transcript were analysed using the concept of curriculum emphasis proposed by Roberts (1982, 2015). Seven curriculum emphases were used as categories in the analysis; everyday coping, the structure of science, science, technology and decisions, scientific skill development, correct explanations, solid foundation, self as explainer (see Roberts, 1982, 2015 and Appendix A). An interview extract was coded, for example, as everyday coping if a teacher had expressed that the reason for teaching science is to help learners understand and relate the teaching and learning of science to everyday occurrences. For instance, a teacher may give an example to help learners understand how electricity is applicable in everyday life.

To find out about the teachers' beliefs about science teaching and learning, we used pre-determined categories from Luft and Roehrig (2007) (see Appendix B). The categories are; traditional, instructive, transitional, responsive, and reform-based. The first two (traditional and instructive) are teacher-centred while the last two (responsive and reform-based) are student-focused while transitional signifies that the teachers' beliefs fall between teacher-centred and student-centred. Teachers' interview data on this dimension was compared against this coding scheme for each question. For instance, under methods of maximising students' learning, if a teacher expressed that they maximise students' learning by providing information in a structured manner, that was categorised as 'traditional' or teacher-centred.

Determining the interaction of STOs and TPK

To determine how the STOs interacted with the TPK, we developed a coding scheme, by relying on the literature on TPK, especially that of Gess-Newsome (2015) (See Table 1). Each STO dimension was examined based on how it influenced the sub-domain of the TPK domains. An episode was taken to have interacted with the TPK sub-domain if the teacher expressed a view or belief during the interview and if that domain was also observed manifesting during a classroom observation. For instance, if the teacher thought the use of analogies and models would help learners understand the science concepts and used these analogies and models in class, it was concluded that there was an influence between the teacher's beliefs about science teaching and learning, an STO dimension, and knowledge of topic-specific representations, a subdomain of TPK (See Appendix C for a sample of a coding scheme).

FINDINGS

Tables 4 and 5 show a summary of how the goals and purposes of science teaching and beliefs about teaching and learning of science influenced TPK domains, respectively. The plus (+) in these tables indicates evidence where the STOs influence TPK domains while the absence of the plus means a lack of evidence, from the observed lessons. These are cumulative from all the observations and not specific to any lesson.

Influence of Goals and Purposes of Science Teaching on TPK Domains

Table 4 shows the specific goals and purposes of science teaching that influenced various TPK domains of the teachers.

Taken holistically, Table 4 shows that almost all of the five teachers' goals and purposes of science teaching appear to have influenced one or two sub-domains of the TPK domains. Solid foundation influenced all the teachers' goals and objectives as the sub-domain of curriculum knowledge excerpt for T4. The teachers' beliefs about solid foundation and structure of science influenced the teachers' pedagogical decisions concerning curriculum knowledge sub-domains: goals and objectives, and linkage to other topics. T1 usually writes lesson objectives on the board at the beginning of the lesson. For instance, he wrote the following objectives on the board:

> Define the meaning of electric current,
>
> Calculate the amount of electric current in a conductor as time elapses,
>
> Construct series and parallel circuits given the tools,
>
> Explain the effect of connecting bulbs in series and parallel in electric circuits

The first two objectives seem to show the teacher's desire for students to achieve a basic understanding of the concept of electric current. This could be the reason why he planned that they define the concept, and later on, perform some calculations. The last two objectives seem to be advanced; requiring students' high level of thinking. Due to the sequence of these objectives, it seems that by including the first two objectives, the teacher wanted to lay a solid foundation for the students. A solid foundation prepares students for future-related topics. Laying of this solid foundation goal influenced linkage to other topic sub-domain as shown in his teaching excerpt below:

Table 4. The influence of goals and purposes of science teaching on teacher professional knowledge

		Goals and purposes of science teaching																	
		T1			T2				T3			T4			T5		
TPK domain	TPK sub-domain	Everyday coping	Solid foundation	Structure of science	Scientific skill development	Solid foundation	Correct explanation	Everyday coping	Correct explanation	Solid foundation	Scientific skill development	Everyday coping	Correct explanation	Structure of science	Solid foundation	Correct explanation	Structure of science
Assessment Knowledge	What to assess		+		+	+			+	+	+	+			+		
	Reasons for assessment														+		
	Methods of assessment				+				+		+	+				+	
Pedagogical Knowledge	Classroom management																
	Student's engagement																
	Instruction strategies		+	+	+	+	+		+	+	+		+		+	+	
Knowledge of Students	Students' differences		+			+											
	Pre-requisite knowledge	+	+				+	+				+			+	+	
	Misconceptions																
Curriculum Knowledge	Goals & objective		+	+	+	+	+	+		+		+	+		+	+	
	Scope and sequence																
	Curriculum coherence																
	Linkage to other topics		+			+											
Content Knowledge	Practices for scientific knowledge generation																
	Core ideas (principles, theories)		+	+		+				+		+			+	+	
	Cross-cutting issues		+														

1 - Teacher : …under geothermal…but the term there is saying 'geo' we know geology, geography?

2 - Students : Yes

3 - Teacher : In geography there we talk about the earth's crust. Hope you have heard of it, huh?

4 - Students : Yes

5 - Teacher : How about 'thermal'? From the thermal expansion of solids topic? Do you remember this term?

6 - Students : Yes

7 - Teacher : Ok. So, what we are saying is that the earth's crust contains rocks, but these rocks are very hot. Now when the water has been trapped in these rocks, we all know that when you are boiling water, there is "this" thing which is produced…?

8 - Students : Yes—Steam

9 - Teacher : So, the trapped water when boiled by these hot rocks produces steam. Now this steam that is coming out is the one which is known as geothermal energy and can be used to drive turbines to produce electricity. Are we clear?

10 - Students : Yes

11 - Teacher : So geothermal is a term that means a kind of energy produced from the heat of the earth crust

It is evident in the above extract that the teacher wants to establish a link between 'geothermal' as an energy source and the prefix 'geo'. That is why in turn 1, he asked if the students are familiar with the prefix 'geo' from geography. The teacher appears to be aware that students are familiar with this term (geo). Hence, as a way of enhancing students' understanding from prior knowledge, he started by tracing the origin of the word 'geothermal'. The prefix 'geo'—a Greek word that means 'earth'. Hence, this prefix combined with thermal, which means 'heat', to form 'geothermal' would mean a kind of energy produced from the earth's crust (turn 11). Not only did he relate the prefix of geo to this new concept, but he also explained the concept of geothermal in relation to content from geography concerning the structure of the earth's crust as shown in turns 5, 7, and 11 as well as other earlier topic in physics, e.g., thermal properties of matter.

For T5, scientific skills development influenced his decisions concerning assessment of students. Evidence for this comes from his delivery of the electricity topic. After explaining one method of magnetisation, the teacher asked the students, as homework, to go into the library to read and write a report on other ways of magnetising a substance as shown in the following excerpt:

1	- Teacher	:	Now let's do this, there are different "methodologies" [*methods*] of charging … well magnetising substances. …
2	- Students	:	*All students listen attentively*
3	- Teacher	:	This one [*points at the stroking method which he had explained to the students*] is an example of those methodologies, stroking, there was a mention of the electrical method, and then you talked about the induced ones all those, so I have just explained the stroking method.
4	- Students	:	*Some students nod in agreement*
5	- Teacher	:	What I want you to do is that you should document the other strategies of magnetising substances, write them … I mean to explain the methodology. You should come up with the method, and then explain how it works … all the methods should be documented and then bring the copies to me so that I mark them. Can you do that by tomorrow?
6	- Students	:	*Students take down the major points of the task*
7	- Teacher	:	Is it possible to do that?
8	- Students	:	Yes

In turn 3, the teacher is telling the students he has only explained one way of magnetising substances—the stroking method. Despite some students' claims of other methods of magnetising such as electrical methods, he acknowledges that what he has done this far is to explain only one method. In turn 5 he, therefore, asks the learners to research and discuss other ways of magnetising substances. Hence, the teacher used homework as a mode of assessment at the same time he is also teaching about scientific skills.

Science teaching should be a situated process in the sense that teaching and learning should be linked to everyday life (Glynn & Winter, 2004). We, therefore, expected to have a lot of instances illustrating this. On the contrary, as can be seen from Table 4 that this was only observed in a few instances. Only two teachers (T1 and T2) had cases that illustrated the influence of everyday coping on the knowledge of students and curriculum knowledge domains. For instance, everyday coping influenced T2's knowledge about students. While teaching about machines, T2 tended to ask questions that related to the students' experiences. The teacher justified his use of students' prior knowledge in the interview by arguing that; "students are familiar with these things, but they do not know the principle behind their operation. So, asking them questions that relate to their lives acts as an eye-opener to see the application of the theory in everyday life". This was evident during instruction, as shown in the extract below:

1	- Teacher	:	Now that we have looked at the issue of Biomass, I want to ask you this question. Have you ever seen where some people close the filled up waste pit and put some pipes where they collect gas?
2	- Students	:	Yes
3	- Teacher	:	Good. So, on the biomass there we are saying it is the energy from the fermentation of organic materials, animal wastes as well as industrial wastes…. produce a number of things including gas. So, the gas there is going to be trapped—is going to be produced by this—the biogas digester
4	- Students	:	*Students listen*
5	- Teacher	:	Now let's talk about Geothermal energy. How many of you are from Liwonde?
6	- Students	:	Us. *Only a few students raise their hands to acknowledge that they are from Liwonde.*
7	- Teacher	:	Are you familiar with a place called *Mawira*?
8	- Students	:	No
9	- Teacher	:	Do you know why this place is known as "*Mawira*"?
10	- Student	:	Boiling. *Mawira* is a vernacular term that means boiling
11	- Teacher	:	Ok, so there is a place in Liwonde which is known as Mawira just because at this place hot water comes out naturally. This is what constitutes geothermal energy…so under geothermal but the term there is saying 'geo' we know geology, geography?

In the above extract, the teacher wanted to use examples that students are familiar with. When he asked if they are familiar with a place known as Mawira and why the place is known by that name. This illustrates the influence of everyday coping.

The Influence of Teachers' Beliefs about Teaching and Learning of Science on TPK Domains

In Table 5, we show the influence of teachers' beliefs about teaching and learning on the various TPK domains. Numbers from 1 to 7 are the beliefs items (see Appendix B for descriptions).

Table 5. Beliefs about teaching and learning of science and teacher professional knowledge domains

				Teacher professional Knowledge Domains															
				Assessment knowledge			Pedagogical knowledge			Knowledge of students			Curriculum knowledge				Content knowledge		
	Teacher	Beliefs items	Categories	what to assess	Reasons for assessment	Methods of assessment	Classroom management	Students engagement	Strategies for differentiation	Students differences	Pre-requisite knowledge	Misconception	Goals and objectives	Scope and sequence	Curriculum coherence	Linkage to other topics	Knowledge generation	Core ideas	Cross-cutting issues
Beliefs about teaching and learning of science	T1	1	T					+	+	+	+							+	+
		2	T						+	+			+					+	
		3	I	+		+													
		4	Tr										+	+					
		5	Tr																
		6	T						+	+									
		7	I	+		+													
	T2	1	T					+	+	+	+								
		2	Tr						+									+	
		3	I	+		+													
		4	Tr										+	+		+			
		5	I																
		6	Tr					+	+	+									
		7	Tr	+		+													
	T3	1	T						+	+			+						
		2	T															+	
		3	I	+		+													
		4	Tr										+	+					
		5	I																
		6	T						+	+									
		7	I	+		+													
	T4	1	T							+	+								
		2	Tr						+	+								+	
		3	I	+		+													
		4	Tr										+	+					
		5	Tr																
		6	T							+									
		7	Tr	+		+													
	T5	1	T							+	+								
		2	T						+	+								+	
		3	T	+	+	+								+					
		4	Tr										+	+					
		5	I																
		6	T						+	+									
		7	I	+		+													

Note: T=transitional; Tr=Traditional; I=Instructive

As can be seen in Table 5, there is a fair distribution of the influence of the teachers' beliefs about science teaching and learning on various TPK domains. Firstly, teachers' beliefs about maximising students' learning influenced teachers' knowledge of students. For instance, when T2, who held transitional beliefs (from interviews) about maximizing students' learning (item number 1) asked questions that allowed the students to recall the basic units, especially the units of mass, and temperature as well as the recalling the skills for conversion of mass from grams to kilograms as well as the conversion of temperature from degrees Celcius to Kelvins when he was teaching about specific heat capacity. During the interview, we noted that T2 referred to this as an example by stating, "conversion of some units during calculation is forgotten by the students". This explains his practice for wanting the students to recall this basic knowledge and skills. The belief is that once students are aware of these, they will not have problems making conversion of units during calculations.

Secondly, teachers' beliefs about science teaching and learning influenced instruction strategies as a sub-domain of pedagogical knowledge. During the interviews, it was evident that the teachers seem to be aware of the challenges associated with differentiated classrooms during instruction. For example, T3 who held transitional beliefs concerning maximising students' learning used the Predict Observe Explain (POE) teaching strategy. The POE teaching strategy was developed by Gunstone and White (1992), to actively engaged students in the teaching and learning process as the students predict and state a reason for their forecast concerning a phenomenon. Through the use of this strategy, the teacher was able to engage the learners in the thinking process, as shown in the extract below:

1.	-	Teacher	:	Ok, so we have been looking at the issue of pressure, and we have defined it and we know how to calculate pressure. Now we want to look at the pressure in liquids, by the way, do we have pressure in liquids?
2.	-	Students	:	Yes.
3.	-	Teacher	:	Ok, can you tell us; 'how do you know that there is pressure in liquids?'
4.	-	Student	:	No
5.	-	Teacher	:	So, we should say that there is no pressure in liquids? You said that there is pressure in liquids, and this time you are saying there is no pressure in liquids, so which one do we take?
6.	-	Student	:	We should consider the side where we said there is pressure
7.	-	Teacher	:	There is pressure, then how do you know that there is pressure? Can you tell us any situation that can tell us that there is pressure in liquids
8.	-	Students	:	*Silence*
9.	-	Teacher	:	suppose we have a plastic bag and then we fill that with water. And then you pierce the plastic with a sharp material. What do you think would happen? [shows a chart depicting this information for students to visualize the situation]
10.	-	Student	:	Water will come out
11.	-	Teacher	:	Why?
12.	-	Student	:	Because of pressure
13.	-	Teacher	:	Ok, this just adds something on what you know that there is pressure because the particles in that liquid they move in all direction. Now because they move in all direction, when you create some holes on this plastic bag where you have water in it then the water will be coming out through those what those holes.

In turn 1, the teacher wants the students to predict whether there is pressure in liquids. While students were able to correctly say that there is pressure in liquids, they seemed not to be sure about this. Even though the teacher expected the students to say that there is pressure in liquids, he too was not satisfied with the flip-flopping of students answers as demonstrated in turns 5-8. To ensure that students grasp what he was saying, he decided to paste a chart on the board depicting the scenario described in turn 9. This allowed the students to make observations and later on try to explain what was happening. This illustrated the idea that there is pressure in liquids and the teacher emphasized that this pressure acts in all directions and that is the reason why water came out of the plastic bag. Apart from this, the teacher also used cooperative learning—group work (knowledge of instruction). The teacher also used a bit of a lecture method, especially when he was introducing new concepts. This integration of instructional strategies (lecture, cooperative learning, POE) is a typical illustration of the influence of teachers' beliefs about science teaching on instructional strategies sub-domain.

On the other hand, one teacher (T4) who held instructive—teacher-centred beliefs, about "knowing when students are understanding"—item number 3 in Table 5, influenced his decisions regarding the nature of instruction as well as assessment methods that were used during instruction. In all the lessons observed for this teacher, he dominated the teaching and learning process. Simple question and answer techniques, as well as lecture methods, were characteristics of his lessons. There was little students' involvement in the lesson as the teacher did not plan any activities for the students. Furthermore, there was little that the teacher did to check students understanding of the lesson as shown in the extract below:

1	-	Teacher	:	Do you have any questions?
2	-	Student[s]	:	No
3	-	Teacher	:	If there are no questions, you will show that by answering this question
4	-	Student[s]	:	*Students listen*
5	-	Teacher	:	Remember, these equations are three; this one, this one and this one [*as he points at the three equations on the board*]. But sometimes you are not given straight-forward; they can give you the information and tell you: can you find *I* – the current? You must make *I* in this equation the subject of the formula. So, you must be able to make

			everything they ask you subject of the formula.
6 -	Teacher	:	*Writes down the problem on the board for the students to do*
7 -	Teacher	:	*Students solve the problem written on the board*

As can be seen from the above extract, the only point the teacher checks students' understanding of the concepts is when he asked a very general question as shown in turn 1. Similarly, instead of asking students questions and weave the interaction to engage the students (Khoza & Msimanga, 2021), in turn, 5 he starts dominating by telling the learners what to do when solving problems related to the topic he was teaching. Thus, resembling a traditional method of teaching science.

Thirdly, teachers' beliefs about teaching and learning of science also influenced TPK domains. For instance, T1 who held traditional beliefs about knowing what to teach during instruction (item number 4) influenced teachers' curriculum knowledge especially goals and objectives sub-domain. From all the lessons that we observed for this teacher, all the objectives as well as activities taken from the curricular document and were followed step-by-step. While this might demonstrate little creativity on the part of the teacher, in terms of objectives and activity sequencing, the teacher offered his explanation which illuminates his traditional beliefs concerning the source of teachers' teaching. The source of this belief (as uttered during the interview) was traced to the curriculum orientation workshop which the teacher underwent while the ministry of education was implementing the new science curriculum. During this time, curriculum developers (experts) told the teachers that they will have to follow what the curriculum prescribes for uniformity's sake.

Lastly, Table 5 shows some form of a uniform level of influence between teachers' beliefs about teaching and learning of science and assessment knowledge domains. For instance, almost all the teachers demonstrated to have traditional beliefs concerning assessment aspects such as knowing students' understanding (item number 3) and knowing the occurrence of learning in the classroom (item number 7). These items appear to mostly influence what to assess and methods of assessment sub-domains of the assessment knowledge. We noted that as a way of assessing the learners, the teachers mostly relied on question & answer methods rather than some of the methods that are spelt out in the curriculum such as tests, examinations as well as projects and practical activities as one would expect in science.

Teachers Beliefs about the NOS and TPK

Analysis of the NOS questionnaires showed that the teachers have a relatively comprehensive understanding of the NOS as the third dimension of STO. However, the influence of the NOS on the TPK domains was not explicit in the observed lessons of all five teachers. That is, there was no explicit talk about the NOS either through objectives or links to the NOS during instruction. The only observed instances are where T1 and T5 used practical work when teaching lessons on electricity. T1 asked the learners to do practical work to investigate the behaviour of current in circuits. This implicitly tackles the aspect of the scientific method. We discuss possible reasons for this lack of influence.

DISCUSSION

The purpose of this study was to explore the influence of STOs on TPK domains with five in-service Malawian science teachers using Friedrichsen et al. (2011)'s categorisation of STOs. Firstly, findings in this study indicate that the science teachers' goals and purposes of science teaching influenced their professional knowledge. Even though teachers had different and multiple goals and purposes, consistent with other studies (e.g., Demirdöğen, 2016; Maseko & Khoza, 2021), solid foundation seems to have influenced most of the teachers' TPK domains than others. Several reasons might explain this observation. The first insight comes from what Friedrichsen and Dana (2005) call "central" and "peripheral" goals and purposes of science teaching. Central goals are those that "dominate the teacher's thinking and appear to drive the instructional decision-making process" (p. 225). Hence, solid foundation was central in this case and could have driven the instructional thinking of the teachers. On the other hand, everyday coping did not feature prominently during observation. Perhaps the arrangement of the curriculum, in this case, would offer a better explanation. The Malawi science curriculum is structured in a way that everyday coping is emphasized towards the end of the topic (Ministry of Education, Science and Technology, 2013). Hence, teachers mostly refer to everyday coping when they are teaching the last parts of a particular topic.

Secondly, although there is a traceable influence of teachers' beliefs about teaching and learning of science on TPK, most of their beliefs did not influence the teachers' practice (see Table 5). Mansour (2013) and Ogan-Bekiroglu and Akkoç (2009) also reported similar findings. According to Rollnick et al. (2008), this could be explained by contextual factors such as availability of resources, class size, and students' socio-economic background. Mansour (2013) further notes another aspect of content – policies. One contextual factor that is applicable in this study is class size. For example, Teacher 3, who had around 120 students in his class expressed reform-based beliefs concerning the role of the teacher and how to assess students, conducted his class in a traditional way focusing on question and answer sessions (see Table 5). Even though the teacher would have wanted to do practical work with the students, the limited resources and large class size make this unattainable and therefore he resorted to a mere question and answer session. Regarding the policy factor, high-stakes national examinations determine to what extent teachers can implement their beliefs and practices about teaching and learning of science. Studies (e.g. Aydin, 2012; Aydin et al., 2014) report the effects of examination-based systems on teachers' teaching orientations. Even though teachers might prefer to teach in a particular way, they might be forced to use a different method of teaching to adapt to the demands of the examination-based system. In this study, the teachers, especially those that are teaching in the senior classes (e.g., T5), recognised the importance of conducting practical work; however, did not carry out practical work with his students due to a lack of time and therefore focus on teaching science content so that they cover the whole curriculum.

Thirdly, the findings in this study suggest that there was no influence of the teachers' third dimension of STOs (NOS) and their TPK even though the teachers held correct views of the NOS. This finding is similar to findings of other studies (e.g., Demirdöğen, 2016; Kiran, 2016). This finding further substantiates the argument that having a comprehensive understanding of the NOS does not necessarily translate to the incorporation of the NOS aspects in the teaching and learning process (Lederman & Lederman, 2019). Lederman and Lederman (2019) highlight that the pressure to complete the content, student motivation and lack of appropriate teacher knowledge as several reasons that explain this observation. While these factors seem to be general they are equally applicable in this study. That is, there was a lack of instructional intention to teach the NOS. Furthermore, institutional constraints like student motivation and pressure to cover content are more plausible in explaining the observations made in this study. A recent study by Mesci et al. (2020) notes teachers' self-efficacy as a factor that contributes to teachers' PCK for the NOS.

The lack of influence between teachers' beliefs about the NOS and TPK domains can also be attributed to the structure of the curriculum. The Malawian science curriculum has been designed in terms of what the teachers are supposed to teach and the philosophy behind it. The teachers who took part in this study rely on the curriculum for what they are supposed to teach. This was evident when the teachers spoke about their beliefs about teaching and learning of science. The Malawian science curriculum specifies that, despite the realisation that the NOS is essential, it is presented as a "suggested teaching and learning activity" under the core element of "scientific investigations" (see Ministry of Education, Science and Technology, 2013, p. 55). This implies that it can be included during instruction or left out altogether. Also, there are no corresponding objectives that specifically address the NOS aspects in the curriculum as a topic or in subsequent topics. Furthermore, in the recommended textbooks, NOS is treated as a standalone topic (see Mshanga et al., 2014). This means that aspects of the NOS are not incorporated into other topics.

Even though the teachers understand how science works and what scientific knowledge is, their inability to include aspects of the NOS during instruction demonstrates an apparent lack of a PCK for the NOS. Researchers such as Faikhamta (2013) and Hanuscin et al. (2011) argue that PCK for the NOS is important if teachers are to incorporate the targeted aspects of the NOS during instruction. In other words, the extent to which correct understanding of teachers' knowledge of the NOS would influence their practice depends on how strong their NOS PCK is.

CONCLUSION AND IMPLICATIONS

This was one of the first studies that examined the influence of STOs on TPK domains using Friedrichsen et al.'s (2011) definition of STOs with in-service science teachers in the Malawian context. Firstly, the nature of the influence between STOs dimensions and TPK has revealed an 'influence map' that suggests a teacher training pattern. For instance, most interactions between teachers' goals and purposes of science teaching as well as beliefs about teaching and learning of science were observed on particular sub-domains of teacher knowledge. For instance, the various goals or purposes of science teaching that teachers held interacted with goals and objectives sub-domain of curriculum knowledge. Similarly, these goals and purposes exclusively interacted with instructional strategies of pedagogical knowledge. This map reveals a deeper pattern in terms of the knowledge domains which teacher educators emphasise during pre-service programmes, which is a gap in teacher training that needs to be thought about so that teachers have robust teacher knowledge. Secondly, although there is an influence on the first two dimensions of STOs observed, there was no influence of the third dimension (NOS) on the TPK domains.

The findings of this study have valuable implications for teacher education in Malawi. The NOS needs to be incorporated in the science pre-service teacher preparation programmes as also alluded to by (Erduran et al., 2021). During teacher training programmes, teacher educators should emphasise the importance of the NOS in the teaching and learning process. Furthermore, we concur with Mesci (2020) that teacher educators should ensure that they do activities (such as the development of lesson plans that explicitly include NOS activities) with science pre-service teachers that develop their PCK for the NOS. Once this is achieved, teachers will know the importance of explicit teaching of NOS aspects in all topics.

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REFERENCES

Aydin, S. (2012). *Examination of chemistry teachers' topic-specific nature of pedagogical content knowledge in electrochemistry and radioactivity*. Middle East Technical University.

Aydin, S., & Boz, Y. (2013). The nature of integration among PCK components: A case study of two experienced chemistry teachers. *Chemistry Education Research and Practice, 14*(4), 615-624. https://doi.org/10.1039/C3RP00095H

Aydin, S., Friedrichsen, P. M., Boz, Y., & Hanuscin, D. L. (2014). Examination of the topic-specific nature of pedagogical content knowledge in teaching electrochemical cells and nuclear reactions. *Chemistry Education Research and Practice, 15*(4), 658-674. https://doi.org/10.1039/C4RP00105B

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed). Routledge.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed). Pearson.

Davidowitz, B., & Rollnick, M. (2011). What lies at the heart of good undergraduate teaching? A case study in organic chemistry. *Chemistry Education Research and Practice, 12*(3), 355-366. https://doi.org/10.1039/C1RP90042K

Demirdöğen, B. (2016). Interaction between science teaching orientation and pedagogical content knowledge components. *Journal of Science Teacher Education, 27*(5), 495-532. https://doi.org/10.1007/s10972-016-9472-5

Demirdöğen, B., Hanuscin, D. L., Uzuntiryaki-Kondakci, E., & Köseoğlu, F. (2016). Development and nature of preservice chemistry teachers' pedagogical content knowledge for nature of science. *Research in Science Education, 46*(4), 575-612. https://doi.org/10.1007/s11165-015-9472-z

Demirdöğen, B., & Uzuntiryaki-Kondakçı, E. (2016). Closing the gap between beliefs and practice: Change of pre-service chemistry teachers' orientations during a PCK-based NOS course. *Chemistry Education Research and Practice, 17*(4), 818-841. https://doi.org/10.1039/C6RP00062B

Erduran, S., Kaya, E., Cilekrenkli, A., Akgun, S., & Aksoz, B. (2021). Perceptions of nature of science emerging in group discussions: A comparative account of pre-service teachers from Turkey and England. *International Journal of Science and Mathematics Education, 19*(7), 1375-1396. https://doi.org/10.1007/s10763-020-10110-9

Faikhamta, C. (2013). The development of in-service science teachers' understandings of and orientations to teaching the nature of science within a PCK-based NOS course. *Research in Science Education, 43*(2), 847-869. https://doi.org/10.1007/s11165-012-9283-4

Friedrichsen, P. M., & Dana, T. M. (2005). Substantive-level theory of highly regarded secondary biology teachers' science teaching orientations. *Journal of Research in Science Teaching, 42*(2), 218-244. https://doi.org/10.1002/tea.20046

Friedrichsen, P., Van Driel, J. H., & Abell, S. K. (2011). Taking a closer look at science teaching orientations. *Science Education, 95*(2), 358-376. https://doi.org/10.1002/sce.20428

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK results of the thinking from the PCK summit. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), *Re-examining pedagogical content knowledge in science education* (pp. 28-42). Routledge.

Grossman, P. (1990). *The making of a teacher: Teacher knowledge and teacher education* (Illustrated ed.). Teachers College Press.

Gunstone, R., & White, R. T. (1992). *Probing understanding* (1st ed.). Falmer Press.

Hancock, D. R. (2006). *Doing case study research: A practical guide for beginning researchers*, 122.

Hansson, L., Hansson, Ö., Juter, K., & Redfors, A. (2021). Curriculum emphases, mathematics and teaching practices: Swedish upper-secondary physics teachers' views. *International Journal of Science and Mathematics Education, 19*(3), 499-515. https://doi.org/10.1007/s10763-020-10078-6

Hanuscin, D. L., Lee, M. H., & Akerson, V. L. (2011). Elementary teachers' pedagogical content knowledge for teaching the nature of science. *Science Education, 95*(1), 145-167. https://doi.org/10.1002/sce.20404

Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching, 39*(7), 551-578. https://doi.org/10.1002/tea.10036

Khoza, H. C., & Msimanga, A. (2021). Understanding the nature of questioning and teacher talk moves in interactive classrooms: A case of three South African teachers. *Research in Science Education*, 1-18. https://doi.org/10.1007/s11165-021-10024-8

Kind, V. (2016). Preservice science teachers' science teaching orientations and beliefs about science. *Science Education*, *100*(1), 122-152. http://doi.org/10.1002/sce.21194/

Kiran, B. E. (2016). *Interaction between experienced chemistry teachers' science teaching orientations and other components of pedagogical content knowledge in mixtures*. Middle East Technical University.

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry-The views about scientific inquiry (VASI) questionnaire: VASI QUESTIONNAIRE. *Journal of Research in Science Teaching*, *51*(1), 65-83. https://doi.org/10.1002/tea.21125

Lederman, J. S., Lederman, N. G., Kim, B. S., & Ko. (2012). Teaching and learning of nature of science and scientific inquiry: Building capacity through systematic research-based professional development. In M. S. Khine (Ed.), *Advances in nature of science research*. Springer.

Lederman, N. G. (2007). Nature of science: Past, present, and future. *Handbook of Research on Science Education*, *2*, 831-879. http://www.csss-science.org/downloads/NOS_Lederman_2006.pdf

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497-521. https://doi.org/10.1002/tea.10034

Lederman, N. G., & Lederman, J. S. (2019). Teaching and learning of nature of scientific knowledge and scientific inquiry: Building capacity through systematic research-based professional development. *Journal of Science Teacher Education*, *0*(0), 1-26. https://doi.org/10.1080/1046560X.2019.1625572

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education*, *11*(2), 38-63. http://www.scholarlyexchange.org/ojs/index.php/EJSE/article/download/7787/5554#page=41

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-132). Kluwer Academic.

Malawi National Examinations Board. (2015). *Chief examiners' reports for junior certificate examinations and Malawi senior certificate physics examinations* (pp. 1-17).

Mansour, N. (2013). Consistencies and inconsistencies between science teachers' beliefs and practices. *International Journal of Science Education*, *35*(7), 1230-1275. https://doi.org/10.1080/09500693.2012.743196

Maseko, B. (2020). *Examining the interaction between in-service Physical Science teachers' teaching orientations and teacher professional knowledge (TPK) domains* (Doctoral dissertation). University of the Witwatersrand.

Maseko, B., & Khoza, H. C. (2021). Exploring in-service science teachers' beliefs about goals or purposes of science teaching. *Journal of Baltic Science Education*, *20*(3), 456-470. https://doi.org/10.33225/jbse/21.20.456

Merriam, S. B., & Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. Jossey-Bass.

Mesci, G., Schwartz, R. S., & Pleasants, B. A.-S. (2020). Enabling factors of preservice science teachers' pedagogical content knowledge for nature of science and nature of scientific inquiry. *Science & Education*, *29*(2), 263-297. https://doi.org/10.1007/s11191-019-00090-w

Ministry of Education, Science and Technology. (2013). *Republic of Malawi syllabus for Physics forms 3 and 4.* Malawi Institute of Education.

Mshanga, J. I., Mlatho, J. S., & Mzaza, P. (2014). *Strides in Physics form 1*. Pearson Education Africa.

Nampota, D. C. (2016). Students' perspectives on teacher practices in Physical Science and their implications on inquiry based instruction. In W. Mwakapenda, T. Sedumedi, & M. Makgato (Eds.), *Researching a sustainable environment and sustaining research in Mathematics, Science and Technology Education* (pp. 405-416). Routledge, Taylor & Francis Group.

Ogan-Bekiroglu, F., & Akkoç, H. (2009). Preservice teachers' instructional beliefs and examination of consistency between beliefs and practices. *International Journal of Science and Mathematics Education*, *7*(6), 1173-1199. https://doi.org/10.1007/s10763-009-9157-z

Roberts, D. (2015). Curriculum emphasis. In R. F. Gunstone (Ed.), *Encyclopedia of science education* (pp. 264-279). Springer Reference.

Roberts, D. A. (1982). Developing the concept of "curriculum emphases" in science education. *Science Education*, *66*(2), 243-260. http://doi.org/10.1002/sce.3730660209

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education*, *30*(10), 1365-1387. https://doi.org/10.1080/09500690802187025

Schwartz, R., Lederman, N. G., & Lederman, J. S. (2008). *An instrument to assess views of scientific inquiry: The VOSI questionnaire* [Paper presentation]. The annual meeting of the National Association for Research in Science Teaching, Bartimore BA.

World Bank (Ed.). (2010). *The education system in Malawi*. World Bank.

APPENDIX A

Goals or Purposes of Science Teaching

Curriculum emphasis (goals or purposes of science teaching)	**Description**
Everyday Coping	This goal or purpose of science teaching is about the teaching of science to learners so that they understand or appreciate the importance of science in everyday life.
Structure of Science/nature of science	This goal or purpose of science teaching is about the teaching of science to learners so that they understand and appreciate the basic nature of science e.g., what constitutes scientific knowledge, how scientific knowledge is generated etc.
Science, Technology, and Decisions	This concerns the teaching and learning of science to demonstrate how science relates to other fields such as technology as well as decision making.
Scientific Skill Development	This goal or purpose of science teaching is about the teaching of science to students so that they develop critical scientific skills: problem-solving, instrument manipulation etc.
Correct Explanation	This goal or purpose of science teaching is about the teaching of science to students so that they can explain phenomena in their environment.
Solid Foundation	This goal or purpose of science teaching is about the teaching of science to students in such a way that it prepares them for other related science courses at a higher level such as university hence teaching students science at this certain level prepares them to understand science at a higher level.
Self as explainer	This concerns what the self-conveys in science learning that includes aspects such as cultural values when generating scientific knowledge

APPENDIX B

Teachers Beliefs about the Teaching and Learning of Science as Described by Luft and Roehrig (2007) – Extracted from Maseko (2020)

No	Category	Traditional (teacher-centred)	Instructive (teacher-centred)	Transitional	Responsive (student-centred)	Reform-based (student-centred)
1.	Ways of maximising students' learning	The teacher provides information in a structured environment	Teacher monitors students' actions or behaviour during instruction	The teacher creates a classroom environment that involves the students	Teacher designs the classroom environment to enable the students to interact with each other and their knowledge	Teacher depends upon students to design an environment that allows for individualised learning
2.	Role of the teacher	Focus on information and structure	Focus on providing experiences	Focus on student/teacher relationships or students' understanding	Focus on collaboration between teacher and students	Focus on mediating students' prior knowledge and knowledge of the discipline
3.	Know when the students understand	When they receive the information	When they can reiterate or demonstrate what has been presented	When they give an explanation or response that is related to the presented information	When they can utilise the presented knowledge	When they can apply knowledge in a novel setting or construct something related to the knowledge
4.	What to teach and what not to teach	Decision guided by the adopted curriculum or other school factors	The decision is based on teacher focus or direction	The decision on which some modification is based on students' feedback	The decision is based on students' feedback and other possible factors	The decision is based on students' focus and guiding documents (e.g. research standards)
5.	When to move on to a new topic	Directed by the teacher	Directed by the teacher based on primary students' understanding of the facts and concepts	Teacher decision based on students' feedback or the ability of the teacher	The decision is based on students' feedback that potentially involves revisiting the concepts	The decision is based upon an ongoing evaluation and considers student abilities to demonstrate understanding in different ways. May involve the modification of lessons
6.	Students' best ways of learning science	From the teacher	By mimicking the teacher	By using procedures or guidelines	By encountering and interpreting phenomena	By eliciting, encountering, and constructing their ideas about phenomena.
7.	Knowing when learning occurs	Determined by the action of students during instruction. Emphasis is on order and attention as related to the student	Determined through measures given by the teacher. Emphasis on the correctness of the student response to the measure.	Teachers determine this through subjective conclusions about the student.	Students interact with their peers or the teacher about the topic. Responses are limited or preliminary.	Students initiate significant interactions with one another and the teacher about the topic.

APPENDIX C

Influence of STOs on TPK Domains Coding Scheme – Extracted from Maseko (2020)

STOs	Pedagogical knowledge	Curriculum knowledge
Beliefs about the goals and purpose of science teaching	If a teacher wants to teach about the goals or purposes of science teaching such as scientific skills development, everyday coping etc during a science lesson and decides to use a variety of teaching strategies such as practical work, activity-based instructions, cooperative learning techniques, lecture method, or the use of topic-specific instructional strategies for instance activities, instructional strategies that instance was taken as an influence of goals or purposes of science on Pedagogical knowledge.	If a teacher plans to teach his students about the goals or purposes of science teaching by including objectives that explicitly express these goals or purposes of science teaching, such as "by the end of the lesson students should be able to describe the role of electricity in our everyday life", or students should be able to describe a how they can gadget they could use to detect rains. These indicated an influence of goals and purposes of science teaching on curriculum knowledge.
Views about the nature of science	If a teacher wants to teach about the various aspects of the nature of science and does this by incorporating various teaching methods, the instance was taken as an influence of views of nature of science on Pedagogical Knowledge.	If a teacher considers explicitly embed aspects of views about the nature of science as objectives of the lesson, that instance was taken as the influence of views about the nature of science on curriculum knowledge.
Beliefs about teaching and learning of science	If the teacher beliefs about the teaching and learning of science are reflected in the teaching methods, this demonstrates the influence of beliefs about the goals and purposes of science on pedagogical knowledge.	If the teachers' beliefs about the teaching and learning of science are explicitly linked to aspects of the curriculum knowledge such as in the formulation of objectives or linking concepts to other topics etc, that was taken an influence of beliefs about the teaching and learning of science on curriculum knowledge.