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Physical Sciences Teacher's Epistemic Cognition on Electric Circuits and their Science Teaching Practice

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Abstract. Although a wide range of studies have been conducted on teachers' cognition and their beliefs. The relationship between teachers' epistemic cognition and their teaching practices has rarely been studied. This study aimed to investigate how physical science teachers' epistemic cognition relates to their teaching practices on electric circuits. A mixed-method explanatory sequential design was adopted for this study. A purposive sampling technique was used to sample participants from the accessible population in uMkhanyakude District KwaZulu-Natal province in South Africa. A total number of forty Further Education and Training (FET) Physical Sciences teachers formed the sample. A survey (questionnaire level 5 Likert scale) and semi-structured interviews were used to collect data. The Model of Teacher Epistemic Cognition was employed as the theoretical framework. The data were analysed using the Statistical Package for Social Sciences (SPSS) version 25 using descriptive and inferential statistics. The findings of the study showed that physical science teachers' teaching practices are strongly correlated to ECS (Epistemic Cognition Source), ECJ (Epistemic Cognition Justification), SEA (Simple Epistemic Aim), and ECC (Epistemic Cognition Certainty). Furthermore, there was a negative correlation between complex epistemic aims with teaching practice which accounted for why teachers do not teach electric circuits for conceptual understanding but rather algorithmically mathematical knowledge. Implications for teaching practices particular to electric circuits are discussed. The findings have implications for teaching science and further research into epistemic cognition.

Keywords: Epistemic cognition; Electric circuits; Teacher Epistemic Cognition; Epistemic beliefs; Science teaching practice

1. Introduction

The cognitive processes that teachers employ when making instructional decisions are an understudied barrier to science education reform. Teachers'

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beliefs about knowledge and learning and the goals they set for their learners' learning could provide important insight into what choices they make in the classroom. Since the dawn of democracy, South Africa has undergone various curriculum reforms and efforts have been introduced over the years to improve the teaching practice. Research in science education has demonstrated the importance and centrality of beliefs in human action. The relationship between epistemic cognition and disciplinary learning, comprehension, critical thinking, and instructional strategies is becoming more apparent (Greene & Yu, 2016). Epistemic beliefs and beliefs about knowledge are an important part of epistemic cognition. Greene et al. (2016) defined epistemic cognition as a process involving dispositions, beliefs, and skills regarding how individuals determine what they know, versus what they believe, doubt, or distrust.

There has been an increased focus on science education across the globe in recent years. The United States and other developed nations have been outpaced by other countries in science achievement for years (National Research Council, 2012). The scientific education system has been subjected to numerous reform efforts, but their effectiveness has been limited. A variety of obstacles have been encountered in the development of innovative and research-based practices. Several researchers (Barger et al., 2016; Banilower et al., 2013; Russ & Luna, 2013) found that science education in high schools has poor quality and does not align with research best practices. Less developed countries face significant challenges when it comes to teaching and learning science and mathematics. Most science teachers use the chalk-and-talk method, despite recommendations for research-based practices. In most cases, passive learning activities are used, which are largely teacher-centered (Govender, Maphalala & Khumalo, 2019). Authentic inquiry and the nature of science are underemphasized, which contributes to poor learner outcomes. Due to fragmented scientific knowledge and a lack of authentic scientific inquiry opportunities, students develop partial or incorrect views of science and scientific knowledge (National Academy of Sciences (NAS), 2015). Research on teachers' epistemic cognition has been limited, and most empirical studies have been qualitative (Pellegrino & Wilson, 2015; Maggioni & Parkinson, 2008).

The South African Physical Sciences National Diagnostic Analytical Reports or the chief marker reports from 2018 to 2022 have revealed a decline in performance on the topic of electric circuits. The electric circuit is a topic in the South African National Curriculum statement (NCS) Further Education and Training (FET) that include internal resistance and series-parallel networks and measuring potential difference and current. The diagnostic reports revealed that most of the matriculate (exit level students) lacked knowledge about electromotive force (emf). They could not define emf in terms of energy. Furthermore, most learners still struggle with fully understanding what is meant by potential difference, current strength, and other electricity terms. Most learners are therefore not aware of how the current flows, what the ammeter measures and what the voltmeter measures, and how the internal resistance affects these readings. Although all learners are supposed to complete a practical on internal resistance, they still don't understand how they work. Physical Sciences seem to be a difficult subject for many learners to apply mathematics skills and knowledge. For learners, calculating gradients, reading coordinates, and determining the y-intercept are all challenging. The problems with electric circuits are not unique to South Africa as Burde and Wilhelm (2020) reported that learners analyse electric circuits using current and resistance. Voltage is viewed as a property of current, not an independent quantity.

There is a poor conceptual understanding of direct current electricity by some educators and textbook authors Gunstone, Mulhall, & McKittrick (2009). Regarding current, voltage, and other concepts, teachers are reluctant to discuss their own beliefs. Moreover, many teachers do not understand what potential differences are: they tend to use incorrect terminology and create misunderstandings in their classes (Gaigher, 2014). It is common for science teachers to teach algorithmically rather than conceptually. The use of such teaching techniques may enhance learners' algorithmic problem-solving abilities, while conceptual understanding is not developed as a result. Cognitive processes related to knowledge, such as epistemic cognition by teachers could provide important insights into science teachers' practices. Previous studies (Moodley & Gaigher, 2019; Sandoval, 2016) demonstrated that human action is heavily influenced by beliefs. Teaching and teacher education research demonstrates that teacher thinking impacts teacher practice in a significant way (Popova et al., 2020; Baldwin & Orgill, 2019). Teaching and learning beliefs influence teachers' implementation of curricular reforms, as do small decisions like how much time they spend on a particular topic or how they interact with curriculum materials.

Since epistemic cognition can influence instructional practices and approaches to teaching and learning, we believe it should be an important focus of teacher education and research. Despite this, research exploring how to address teachers' epistemic cognition is relatively underdeveloped, with suggestions often lacking specifics (Lunn-Brownlee, Ferguson & Ryan, 2017). Researchers have, however, had difficulty consistently concluding that teachers' beliefs are reflected in their classroom practices (Ponnok, 2017). It may therefore be useful to investigate how teachers' epistemic cognition on teaching electric circuits relates to their understanding of their teaching practices. Hence, this study examines:

i. How physical science teachers' epistemic cognition relates to their teaching practices on electric circuits?
ii. What are the teaching practices of Physical science teachers on electric circuits?

Theoretical Framework: Model of Teacher Epistemic Cognition

The Model of Teacher Epistemic Cognition (MTEC) was developed by (Buehl & Fives, 2016). The main tenet of the model is that teachers' epistemic cognition is a bifurcation of two main tasks teaching and learning. Buehl and Fives (2016) view epistemic cognition as the teachers' active contemplation of knowledge claims, processes of knowing, and the construction of knowledge. The teacher's active processes are guided by the teacher's self-systems which consist of their prior knowledge, existing epistemic beliefs (ideals), and epistemic vices and virtues (Fives et al., 2017). The MTEC provides a framework for understanding the relationship among teaching tasks, epistemic beliefs, and practice. In their daily work, teachers engage in many complex tasks, including planning lessons, implementing instruction, and assessing student progress (Fives et al., 2017).

According to the MTEC (Figure 1), the teacher must first identify the task, whether teaching or learning. After determining the task, the teacher must determine the domain which includes the following: subject matter, pedagogy, classroom management and organization, child development, context, and self/other (Buehl & Fives, 2016). In teaching practice, educators set epistemic aims for themselves and their learners while integrating multiple domains. This is followed by setting epistemic aims which are limited to knowledge, understanding, and true belief for the teacher and learners. Chinn, Rinehart & Buckland (2014) defined epistemic aims as the goals or intended objectives of cognition and action to achieve epistemic ends including knowledge, true beliefs, justified beliefs, understanding, wisdom, explanation, models, evidence, or the avoidance of false beliefs.

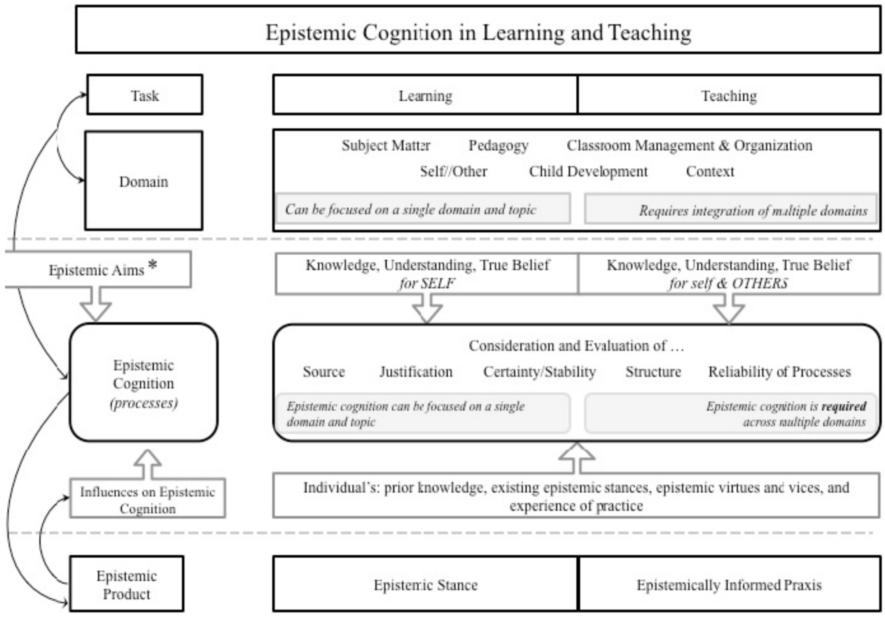

Figure 1. Model of teachers' epistemic cognition (Buehl & Fives, 2016)

These aims can, but do not necessarily overlap with learning objectives. Once the aim has been determined the teacher enters the epistemic cognition (processes). Epistemic cognition is influenced by prior knowledge, existing epistemic stances, and experiences of practice. Epistemic cognition influences require teachers' existing knowledge of the subject matter, curriculum, pedagogical practices, and learners (Buehl & Fives, 2016). It is the teacher's prior knowledge and experience that informs the teacher's practice. Teacher knowledge and experience inform the selection of the teaching method for understanding the learners' learning goals. Buehl and Fives (2016) further argued that the last part of the MTEC epistemic product is a stance on a teacher's position on the certainty of knowledge claims. Epistemic stance reflects the constructed meaning of the idea, concept, or information as situated within the knower's cognitive schema as well as the perspective one holds about the nature of that knowledge (Buehl & Fives, 2016). The framework by MTEC describes how teachers acquire knowledge and how this knowledge is used in their instruction. The epistemic cognition of practising teachers has been shown to significantly impact their teaching methods, strategies, and expectations. Teachers' epistemic cognition is thought to impact their ability to obtain deep understanding during teacher education programs, as well as their ability to make decisions, plan, orchestrate, and assess in subsequent practice. Only a few studies (Fives et al., 2017; Hofer, 2016; Ponnock, 2017) have examined the epistemic beliefs of science teachers. therefore, this research paper will adopt the model of teachers' epistemic cognition as it resonates with the aim of the study.

2. Literature review

Education researchers have long sought to understand how teachers' thinking shapes their teaching practices. Russ, Sherin and Sherin (2016) suggest that conceptualizing teaching practice from the cognitive paradigm allows the teacher's mental life to be viewed as a way of thinking based on a specific set of knowledge and cognitive processes. Epistemic cognition which includes teacher's knowledge, beliefs, identities, and goals has been used by several researchers in an attempt to get an in-depth understanding of teacher practice (DeGlopper et al., 2023; Kradtap Hartwell, 2019). Science education often aims to foster learners' understanding of science's nature (Lindfors et al., 2020) so that they leave school knowing what makes science 'science'. As members of society, learners can evaluate and draw informed conclusions regarding issues about science by understanding the epistemological basis of science. The discovery of electricity has had a profound impact on our civilization. Its fundamental quantities like voltage, resistance, and current, and their relationship in simple circuits, are vaguely understood by the learners (Pitterson & Streveler, 2014). In a study that investigated the teacher's perceptions and learners' alternative conceptions Moodley and Gaigher (2019) reported that most teachers struggled with current, voltage, and other electric circuits concepts. Furthermore, teachers failed to explain the potential difference and used the wrong terminology that confused learners. They concluded that many teachers do not teach electric circuits for conceptual understanding but rather algorithmically. Learners' alternative conceptions are strongly related to how they are taught (Rollnick et al., 2008). The teacher's epistemic cognition may provide important insights into science teachers' choices in the classroom and the reasons that they might or might not adopt different instructional practices based on their beliefs about knowledge and knowledge acquisition as well as goals for learners' knowledge acquisition.

Learners' difficulties regarding electric potential in electric circuits may lie in the way electrostatics and electric circuits are traditionally presented by textbooks and teachers (Guisasola, 2013). Electrostatics chapters emphasize the concepts of electric charge, electric field, and electric potential, but they are rarely mentioned in simple electric circuits. Burde and Wilhelm (2020b) posited that the central role of electric potential in electric circuits is elusive in most classroom activities. Furthermore, the concept is introduced mathematically without venturing into the relationship between potential differences and current. Moodely and Gaigher (2017) posit that there seems to be a lack of consensus among electric circuit curriculum developers regarding what concepts should be emphasized. Some believe that electric current should take centre stage more than potential differences. Thus, investigating teachers' epistemic cognition could provide important insights into the choices science teachers make in the classroom.

Tsai (2007)investigated teacher practices by exploring science teachers' scientific epistemological views (SEVs) and their teaching beliefs. The findings revealed that teachers with a positivist approach tended to have a positivist approach towards their teaching approaches. On the other hand, those with constructivist-aligned SEVs used constructivist teaching practices. Learners' perceptions of their science classroom were influenced by the teachers. Epistemic cognition concerns ideas people hold about the nature and acquisition of knowledge. Gholami and Husu (2010) described epistemic cognition as a process that includes, inquiry goals and the value associated with achieving those goals (i.e., epistemic values and aims); how knowledge is structured; the origins of knowledge, the reasons for one's beliefs, and how one feels towards ideas; dispositions that support or hinder epistemic aims; and the processes for achieving epistemic aims.

Teachers' epistemic cognition plays an integral part in how they interpret knowledge, justify the structure and source of information, and more generally how the learning process unfolds (Gholami & Husu, 2010). In teacher education programs, teaching practicum is viewed as an integral part (Borg, 2006; Tang et al., 2007), and teachers' initial conceptualizations of teaching, pedagogical decisions, and classroom activities are filtered through their EC (Cheng et al., 2009). To be more precise, EC has found its place in education as a factor that impacts many aspects of learning and teaching including learning motivation and instructional practices (Ng, Nicholas & Williams, 2010). Teachers' practice reflects their hidden assumptions and beliefs about how to run a classroom, what to cover, what materials to use, and teacher-learner interaction to be selected. Ponnock (2017) agrees that the findings on teaching beliefs and practices had been inconsistent. The inconsistencies might be caused by the conflicting epistemic traditions between the two domains of science and education. Roth and Weinstock (2013) acknowledge that several studies have focussed on the relationship between beliefs and practices in different disciplines. However, there is a paucity of studies that are topic specific in science. The researchers are of the idea that teaching practices might be rooted in how teachers perceive knowledge and define knowledge-gaining resources.

3. Methodology: research design

According to Creswell and Clark (2017), the research design is regarded as an overall technique where you choose to merge the various components of the research coherently and rationally where the researcher successfully addresses the research problem. This study employed a sequential mixed-method research design. The different weight design (Quan-qual) was used by giving greater weight to quantitative methods (questionnaire survey) and less weight to qualitative methods (interviews). The purpose of the mixed-method design was to obtain a richer and more reliable understanding (broader and deeper) of a phenomenon than a single approach would yield (Cohen, Manion & Morrison, 2018).

3.1 Context and Participants

The target population of this study was all grade 11 high school physical sciences educators for Further Education and Training (FET) in South Africa. The accessible population was forty physical sciences teachers from surrounding schools in the uMkhanyakude district in the KwaZulu-Natal province of South Africa. The teachers were attending physical sciences community engagement training workshops. According to(Cohen et al., 2018) an accessible population comprises of sub-population of the target population which is close enough to the researcher. A purposive sample of eight teachers (four females and four males) was selected for interviews. The time frame for each interview session ranged from 15 to 20 minutes. Due to the global pandemic, Covid-19, all necessary health protocols were observed such as maintaining social distancing, using face masks throughout the sessions, and sanitizing regularly. Interviews were conducted face to face and all Covid -19 safety majors were observed. This study focused on the physics part of physical sciences on the topic of electric circuits. The topic requires the learners to know about emf, terminal Potential Difference (terminal pd). Furthermore, PD should be defined in terms of work done and charge ($V = W/Q$). Voltage and potential difference are synonymous. Practical demonstrations focused on measuring emf and pd and account for the difference in electric circuits.

3.2 Instrumentation

Questionnaires are written instruments that elicit reactions, beliefs, and attitudes from subjects. It is a common technique for collecting data in educational research and most survey research uses questionnaires. In the present study, three questionnaires were selected. The first questionnaire was one developed by the (Hofer, 2000) discipline-focused epistemological beliefs questionnaire (DFEBQ). The DFEBQ was used to measure teachers' epistemic beliefs about knowledge of electric circuits. According to Cazan (2013), the "DFEBQ is a 21-item self-report instrument (using 5-point Likert scale, reliability $\propto = 0.51 - 0.81$) designed to assess four dimensions of epistemic beliefs: the source of knowledge (example of item: "If you read something in a textbook for this subject, the certainty ("Truth is unchanging in this subject"), simplicity of knowledge ("Ideas in this subject are complex"), and the justification of knowledge ("A theory in this field is accepted as true and correct if experts reach consensus")".

The second questionnaire measured the science teaching practices questionnaire (Likert scale 1-5, reliability = 0.82 - 0.88) adapted from (Supovitz & Turner, 2000). The questionnaire was divided into two Teachers' Investigative Practices and Teachers' Classroom Culture of Investigation. The third questionnaire was the epistemic aims adapted from (Chinn et al., 2014). It consisted of ten questions (Likert scale of 1-5) that explored teachers' epistemic aims on electric circuits.
Using Luft and Roehrig's (2007) teacher belief interview, teachers responded to four open-ended questions. Interview requests were sent to everyone involved in teaching FET Physical sciences in the uMkhanyakude district over the last five years. We chose to restrict invitations to teachers who had taught in the last five years because we assumed they would still remember details of how they approached teaching electric circuits. To determine the content validity, the questionnaires were examined by four high school physical sciences teachers

outside the sample space. Content validity was established by presenting the questionnaire and objectives to teachers to ensure that the content fall within the scope. Teachers were requested to fill out a checklist (yes or no) followed by remarks on each question.

The interviews were transcribed through Zoom, and some of the utterances were broken down into small sections of particular ideas which were then coded. Approval to conduct the research was applied from the University of Zululand Research and Ethics Committee through the completion of the ethical clearance application form. After it was awarded by the University, permission was applied to the Department of Basic Education of the KwaZulu-Natal province to conduct the research. Permission was granted to conduct the research around the district.

3.3 Data Analysis

Data analysis is referred to as a process of collecting, modelling, and analyzing data to extract insights that support decision-making (Calzon, 2021). The completed questionnaires were submitted to a statistician for data capture and coding. Thereafter, descriptive, and inferential statistics were used to analyse quantitative data. Inferential statistics included finding the correlations and testing the hypothesis. The data were analysed using the Statistical Package for Social Sciences (SPSS) version 25. The data from the Likert Scale questionnaires were analysed using De Winter and Dodou's (2010) step-by-step analysis of Likert scale data. Likert data are ordinal, discrete, and have a limited range. These properties violate the assumptions of most parametric tests. A parametric test assumes that the data are continuous and distributed normally. In nonparametric tests, no normal distribution is assumed, and hence they are accurate with ordinal data. Therefore, the first step was to test for the normality of the Likert scale data. Harpe (2015) suggests that the analysis of Likert scale data is dichotomous. If the data is normally distributed, then parametric methods which include linear regression and Pearson correlation are used. Qualitative data from open-ended questions were analysed through a process called content analysis. Content analysis is a more practical method of analyzing data that can be used quantitatively or qualitatively (Cohen *et al*,. 2018). Content analysis involves identifying words, themes, or concepts within data. The transcribed interview contents were categorized into the main themes. Themes are broad categories of common information related to a research phenomenon that summarize its dimensions.

4. Findings

The data from the Likert scale questionnaires were subjected to SPSS version 25. Normality tests were computed as they are important since all parametric statistical tests rely on an assumption of normality (Dag, Dolgun & Konar, 2018). The Shapiro-Wilk test was calculated to test for normality. The null hypothesis for this test of normality is that the Likert scale data is normally distributed. A null hypothesis is rejected if the significant level $p < 0.05$. The probabilities levels for both tests $p < 0.05$ are evident in Table 1 and thus the null hypothesis that the sample comes from a normal distribution is rejected.

Table 1: Shapiro-Wilk test for normality (n=40)

	Statistic	df	Sig.
SEA	.899	40	<,001
CEA	.948	40	.028
ECS	.964	40	.033
ECJ	.950	40	.034
ECC	.963	40	.020
ECST	.923	40	.003
STIP	.8654	40	.002
STIC	.0914	40	.003

Key: Simple Epistemic Aim (SEA); Complex Epistemic Aim (CEA); Epistemic Cognition Source (ECS); ECC (Epistemic Cognition Certainty); ECST (Structure); Epistemic Cognition Justification (ECJ); Science Teaching Investigative Process (STIP); Science Teaching Investigative Culture (STIC).

The Kolmogorov-Smirnov normality test is used when the sample participants are greater than 100. Thus, the present study adopted the Shapiro-Wilk test since the sample was less than 100. The level of significance for all the variables is ($p < 0.05$) and the null hypothesis (the sample comes from a normal distribution, and the alternative hypothesis is that it does not) is rejected, and the data is not normal and further analysis was done using nonparametric methods.

As a predictive analysis, ordinal regression was employed to explain the relationship between one dependent variable and two or more independent variables. In ordinal regression analysis, the dependent variable is ordinal, and the independent variables are ordinal or continuous-level. In the present study, both independent and dependent variables are ordinal. Ordinal Regression Analysis is used for three major purposes: causal analysis, effect forecasting, and trend forecasting (Papaoikonomou, 2021). Ordinal regression was performed on the Likert scale data to analyse how the epistemic aims and epistemic cognition relates to science teaching practices. The model-fitting information data tells how well the data fits in the model. Table 2 shows the significance ($p< 0.05$) and concludes that the data fits in the regression model. The goodness of fit also shows how the data fits in the model.

Table 2: Model fitting information

Model	**2 log-likelihood**	**Chi-square**	**Df**	**Sig**
Intercept only	276.936			
Final		55870	7	< 0.001

The Person and Deviance significance is ($p> 0.05$) where the significance of the Person is 0.88 and deviance is 1.00. As a measure of goodness of fit in linear regression, the squared multiple correlations, $\mathbf{R^2}$, represent how much variance is explained by each predictor. In Table 3 Nagelkerke shows that 67.5% of the change in teaching practices is a result of the independent variables.

Table 3: Goodness of Fit

	Chi-square	sig	Pseudo-R-square	
Pearson	864930	.880	Cox and Snell	.673
Deviance	219680	1.00	Nagelkerke	.675
			Mc Fadden	.201

Parameter Estimators

The parameter estimates in Table 4 summarise the effect of each variable. For covariates, positive (negative) coefficients indicate positive (inverse) relationships between independent variables and teaching practices. An increasing value of a covariate with a positive coefficient corresponds to an increasing rate of teaching practices. The parameter estimates are interpreted as coefficients. They show how independent variables affect the dependent variable. From Table 4, all five independent variables are statistically significant and ($p < 0.05$.) only one variable ECC has a negative estimate, the rest has a positive estimate.

Table 4. Parameter estimates.

Location	Estimate	Std Error	df	Sig
SEA	.714	.414	1	.001
CEA	.210	.595	1	.023
ECC	0.593	.668	1	.013
ECS	.602	.584	1	.030
ECJ	.544	.446	1	.041
ECST	-1.213	.345	1	.036

For every one-unit increase on the ECST, there is a predicted decrease in teaching practices. This simply means that as the value of ECST increases there is a decreased probability of failing good teaching practices. The other four variables are positive estimates which means for one unit increase in the variables there is a predicted increase in the teaching practices. A coefficient describes the size of the contribution of that predictor; a near-zero coefficient indicates that the variable has little influence on the response. The sign of the coefficient indicates the direction of the relationship. Thus, CEA and ECST are near zero and have little influence, and ECS and SEA have a great influence on teaching practices.

Correlation

To gain a preliminary understanding of the relationships between constructs, we conducted bivariate correlations with epistemic beliefs, epistemic aims, and teaching practices. We conducted bivariate correlations with all the variables. The Spearman rank-order correlation coefficient is a nonparametric measure of the strength and direction of association that exists between two variables measured on at least an ordinal scale (Dag et al., 2018). In the present study, Spearman's correlation was calculated to understand whether there is an association between the dependent and dependent variables. Harpe (2015) suggests that Spearman's correlation should satisfy three assumptions. Firstly, bivariate variables should be measured on an ordinal (e.g., Likert scale). Secondly, the two variables represent paired observation. Thirdly, there should be a monotonic relationship. The Correlation Coefficient is the actual correlation value that denotes magnitude and direction, the Sig. (2-tailed) is the p-value that is interpreted, and the N is the number of observations that were correlated.

Table 5: Spearman correlation (rho) of the variables

Correlations

			SEA	CEA	ECC	ESC	ECJ	ECST	STIP	STIC
Spearman's rho	SEA	Correlation Coefficient	1.000	.309*	.381**	.247	.342*	.258	.312*	.256
		Sig. (2-tailed)	.	.033	.007	.090	.017	.073	.031	.075
		N	49	48	48	48	48	49	48	49
	CEA	Correlation Coefficient	.309*	1.000	.243	.434**	.187	.266	.327*	.352*
		Sig. (2-tailed)	.033	.	.097	.002	.204	.068	.023	.014
		N	48	48	48	48	48	48	48	48
	ECC	Correlation Coefficient	.381**	.243	1.000	.516**	.223	.114	.108	.182
		Sig. (2-tailed)	.007	.097	.	<,001	.128	.442	.464	.216
		N	48	48	48	48	48	48	48	48
	ESC	Correlation Coefficient	.247	.434**	.516**	1.000	.179	.432**	.264	.237
		Sig. (2-tailed)	.090	.002	<,001	.	.223	.002	.070	.105
		N	48	48	48	48	48	48	48	48
	ECJ	Correlation Coefficient	.342*	.187	.223	.179	1.000	.499**	.680**	.711**
		Sig. (2-tailed)	.017	.204	.128	.223	.	<,001	<,001	<,001
		N	48	48	48	48	48	48	48	48
	ECST	Correlation Coefficient	.258	.266	.114	.432**	.499**	1.000	.611**	.697**
		Sig. (2-tailed)	.073	.068	.442	.002	<,001	.	<,001	<,001
		N	49	48	48	48	48	50	48	50
	STIP	Correlation Coefficient	.312*	.327*	.108	.264	.680**	.611**	1.000	.884**
		Sig. (2-tailed)	.031	.023	.464	.070	<,001	<,001	.	<,001
		N	48	48	48	48	48	48	48	48
	STIC	Correlation Coefficient	.256	.352*	.182	.237	.711**	.697**	.884**	1.000
		Sig. (2-tailed)	.075	.014	.216	.105	<,001	<,001	<,001	.
		N	49	48	48	48	48	50	48	50

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

All the variables were statistically significant of a bivariate association between the two ordinal variables since the p-value was less than 0.05. Higher rho coefficients denote a stronger magnitude of the relationship between variables. Smaller rho coefficients denote weaker relationships. Thus, from Table 5 ECS, SEA, ECJ, and ECC have higher coefficients which shows a strong relationship with teaching practices.

Qualitative Data (Interviews)
Purposive sampling was done, bearing in mind gender balance to select four male and female physical sciences teachers. To maintain anonymity, the teachers were assigned alphabetic letters from A to H. An interview schedule was used to maintain uniformity in the questions asked of each teacher. All the interviews were recorded with the consent of the participants and were later transcribed verbatim.

Interview Questions 1: How do you maximise learner learning in your classroom?

> **C**: *To maximise learning time, it is essential to plan and prepare effectively. I feel okay when I spend more time on making learners motivated, interested, and engaged. Electric circuit boards if available would help in the engagement but the lack of resources lead me to*

improvise. I ask learners to bring cells and electric wires and we spend most of the time making the circuits.

D: *To maximise learning I plan my lesson to maximise time on task and learner engagement.* *My focus is on taking more time on activities on electric circuits and assessing the learners. I draw my satisfaction when most learners lift their hands and get correct answers. To me, it's a sign of deep and meaningful learning.*

The two responses show that proper planning of the lesson and engagement of the learners is key to maximising learning in the classroom. Though planning reveals the epistemic cognition process the engagement seems to focus on learners doing many questions in the classroom activities.

The second question was how do your learners learn electric circuits best?

A: *They learn best when they are engaged. Ideally, I would like to do experiments, but I demonstrate. Furthermore, we build our electric circuits in class and link the topic to real-life examples.*

G: *Learning electric circuits best requires learner-centred approaches. Providing the learners with a lot of opportunities to engage and define important concepts such as voltage and current is the best. In my own view guided inquiry is the best. The problem lies in that we tend to teach the way we were taught.*

The responses acknowledge that learner-centred approaches are the best. Both view guided inquiry as a way to improve learning. The epistemic aims of the learner and the teacher are captured, the teacher guides and the learners are engaged.

The third question was how do you describe your role as a teacher?

B: *My role as a teacher is to be the facilitator. However, because I am in a rural setting I revert to chalk and talk. I resort to the mathematics part of calculating voltage and current.*

E: *As for me, I use the teacher-centred approach. The topic has terms I still have problems expressing.*

Teacher B response shows that facilitation might be suitable but lack of resources in rural schools force them to revert to chalk and talk. On the other hand, teacher E has problems with terms in electric terms. Thus, the role of the teacher being a facilitator is clear but teachers content knowledge and resources can limit.

The last question was how do you decide what to teach and what not to teach on electric circuits? The question required the teachers to state their epistemic and non-epistemic aims when teaching electric circuits.

F: *All that I teach is determined by what's in the NSC CAPS Physical Sciences.*

G: *The CAPS document guides me on what to teach, I do not add anything.*

The responses show that the teachers dwell on the epistemic aim of the curriculum documents and do not bother to venture into the non-epistemic aims of the topic of electric circuits. Overall, the teacher's epistemic cognition is strongly influenced by their beliefs and the way they were also taught.

5. Discussion

This study followed two-fold research questions: RQ1- what is the relationship between teachers' epistemic cognition of electric circuits and their understanding of their teaching practices? RQ 2 was what are the teaching practices of Physical science teachers on electric circuits. This study showed that physical science teachers' teaching practices are strongly correlated to ECS, ECJ, SEA, and ECC. Both quantitative and qualitative results indicated that physical science teachers are inclined to learner-centred and constructive practices of teaching electric circuits. The physical sciences teachers mainly believed learning of electric circuits occurs best when learners are engaged and given activities. The correlation between epistemic belief of the certainty of knowledge and teaching practices on electric circuits was high, implying that truth is not changing on this topic. The simple epistemic aims also influenced their teaching practices. On the other hand, Complex epistemic aims (CEA) had a low correlation meaning that teachers were not challenging learners' alternative conceptions. The findings agree with Gholami and Husu (2010) who suggested that teachers' epistemic cognition plays an integral part in how they interpret knowledge, justify the structure and source of information, and more generally how the learning process unfolds. The epistemic belief in the certainty of knowledge of electric circuits had a strong bivariate correlation with teaching practices. This finding reflects the idea that teachers trust and rely on textbooks. Garzón et al. (2014) suggested that learners' difficulties regarding the electric potential in electric circuits may lie in the way electrostatics and electric circuits are traditionally presented by textbooks and teachers. Textbooks rarely emphasise the concepts of electric charge, electric field, and electric potential on simple electric circuits. Burde *et al*., (2020) suggested that the central role of electric potential in electric circuits is elusive in most classroom activities. Additionally, the concepts of electric circuits are introduced mathematically without venturing into the relationship between potential differences and current.

Teachers' practice reflects their hidden assumptions and beliefs about how to run a classroom, what to cover, what materials to use, and teacher-learner interaction to be selected. Analysis of qualitative data revealed that teachers maximise learning through engagement and activities. The engagement recommended guided inquiry, yet the teachers practised chalk and talk methods. The epistemic cognition in teaching and learning revealed that teachers would use guided inquiry and engagement. The findings of this study suggested that the teachers considered teaching electric circuits by moving away from didactic approaches to guided inquiry. Though learner-centered instructional approaches were mentioned learner-centered tasks such as group discussion, role-play activities, and pair talks demanding the learners' activity were rarely discussed. The finding verifies Ponnock's (2017)relationship between teaching beliefs and practices had been inconsistent. The inconsistencies might be caused by the conflicting epistemic traditions between the two domains of science and education. The results of this study have shown that the conflict may be a result of teachers struggling to teach guided inquiry.

6. Conclusion and Recommendations

In this study, we explored the relationship between Physical Sciences teachers' epistemic cognition of Electric circuits and their science teaching practices. This study showed that physical science teachers' teaching practices are strongly correlated to ECS, ECJ, SEA, and ECC**.** Furthermore, there was a negative correlation between complex epistemic aims with teaching practice which accounted for why teachers do not teach electric circuits for conceptual understanding but rather algorithmically mathematical knowledge. The findings of this study seem to support that epistemic cognition of teaching and learning tasks and domain determines teaching practices. This research study did not observe the lessons in the classrooms to characterize epistemic cognition. The findings reported herein indicate that future research should focus on teachers' classroom instructional practices and their epistemic cognition. The findings of the present study seem to suggest that one variable of the epistemic cognition process certainty of knowledge has a strong correlation with teachers' practices. The certainty of knowledge may affect how learners are engaged during lessons.

The findings reported in this study suggest that teachers need additional opportunities to improve the epistemic cognition of teaching and learning. Teachers' attention needs to be directed to the fact that terms such as current, voltage, and electric potential must not be done using mathematics algorithmically. Future research could also target primary school teachers and university lecturers to allow for an exploration of differences in epistemic cognition when teaching electric circuits. Another interesting possibility for a future investigation would be a comparison between teachers' and learners' epistemic cognition.

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Appendix A

Interview Questions

The four questions were as follows:

1) How do you maximise learner learning in your classroom?
2) How do your learners learn electric circuits best?
3) How do you describe your role as a teacher? and in the school setting,
4) How do you decide what to teach and what not to teach on electric circuits?