JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

EXPLORING PHYSICS TEACHERS' TECHNOLOGICAL, PEDAGOGICAL AND CONTENT KNOWLEDGE AND THEIR LEARNERS' ACHIEVEMENT IN ELECTRICITY

Jonas Kwadzo Kotoka,
Jeanne Kriek

Abstract. *The technological, pedagogical and content knowledge (TPACK) framework was developed incorporating content, pedagogical and technological knowledge. Studies used TPACK constructs and reported on teachers' TPACK and student learning, but none explored the correlation between teachers' TPACK and the achievement of their learners. This research followed an exploratory correlational research design involving 1423 Grade 11 learners and their 42 Physics teachers in a South African district after electricity was taught. A self-report questionnaire may not truly measure teachers' TPACK, therefore, learners' perceptions of their teachers' use of technology were explored. The correlation between the Physics teachers' TPACK and the achievement of their learners in electricity was established. Four validated research instruments were used, namely, the Learner Electricity Achievement Test (LEAT), the Learner Confirmatory Questionnaire (LCQ), the Teachers' Technological, Pedagogical and Content Knowledge Questionnaire (T-TPACKQ) and the Learners' Confirmation of the Teachers' Technological, Pedagogical and Content Knowledge Questionnaire (LC-T-TPACKQ). Findings indicate a statistically significant difference between teachers' views of their TPACK and the views of their learners. The correlation between teachers' TPACK and the achievement of their learners was not statistically significant. These results can influence the professional development of teachers in respect of the use of technology in teaching.*

Keywords: *electricity teaching, student achievement, learner views, technological pedagogical and content knowledge (TPACK), teacher views*

Jonas Kwadzo Kotoka, Jeanne Kriek
University of South Africa, South Africa

Introduction

A dynamic society necessitates a change in the way learners learn. This could require a need to incorporate technology to be able to motivate learners and keep their interest in the learning process (Li, 2016). Teachers have to prepare their learners to realise that they cannot believe everything they see. Teacher-centred teaching in which teachers are the sole providers of information, cannot sustain the interest of learners and are not effective in modern-day classrooms (Khine et al., 2017).

Recent studies show that technology has become vital in advanced interactive lessons (Al-Hariri & Al-Hattami, 2017; Koh et al., 2017; Kotoka & Kriek, 2014). However, to enhance the quality of student achievement, teachers need to use the technology effectively, but it is not easy (Khine et al., 2017). The inclusion of technology in the classroom not only requires careful planning but includes the identification of suitable technology to enable learning (Kriek & Coetzee, 2016). The choice of suitable technology and how it is implemented is significant to facilitate understanding.

There are two main reasons for settling on electricity as a topic in the current study. Firstly, at all levels of education, electricity is found in all physics curricula. As early as grade 8 in South African schools, electric circuits and electricity are introduced to high school learners, the basic principles should be revisited and practised continuously as they constantly remain a challenge for learners in the higher grades (DBE 2020). Knowledge of electricity is essential for many topics and their applications in our daily lives. These topics include but are not limited to generators and motors, electromagnetism, and alternating current electricity. Most importantly, 35 marks out of the 150 marks in the grade 12 matriculation examinations, are allocated to electricity and magnetism (DBE, 2011 p. 1183). Secondly, concepts in electricity are abstract and complex. Therefore, electricity is regarded as problematic such that understanding electricity is dependent on analogies. Teachers have difficulty teaching the topic due to learners' inability to visualize the basic topics like; resistance, electric current and potential difference (Stavrinides et al., 2015). This view is supported by Moodley and Gaigher (2017), who noted that Physics teachers have poor teaching techniques and thin conceptual understanding.

https://doi.org/10.33225/jbse/23.22.282

Research Problem

Pre-service teachers were trained to use technology when teaching and it was expected from them to integrate it during their teaching practice lessons (Mouza et al., 2014). These researchers explored how this influenced these pre-service teachers' TPACK and practice. Results indicated that they applied their knowledge in practice, though "there was variability in the ways in which knowledge domains were represented in participants' narratives" (p. 206). These findings were supported by Ogan-Bekiroglu and Karabuz (2017) when they examined pre-service Physics teachers' knowledge domains (TPACK) and their technology integration skills in practice. The impact of acquiring knowledge with e-TPACK[1] on teacher trainees' TPACK was examined in another study (Christodoulou, 2018). Findings from these mentioned studies indicated that teachers in training who specifically learnt how to use e-TPACK achieved better in terms of developing TPACK proficiencies than the learners in the group chosen as control.

As part of their development, teacher trainees were offered chances to learn from in-service teachers when they engage in teaching practice. During one of these teaching practice sessions, trainee teachers were asked to evaluate the practising teachers' use of TPACK (Celik et al., 2015). The researchers in Celik's study presented 15 case studies in different subject areas and academic levels. Their findings indicated that all the teachers had the necessary content knowledge, but the age of the teachers (above 45) influenced their use of technology. Because of their age, they had insufficient knowledge of how to implement educational technologies when teaching. In another study, Jang and Chang (2016) asked learners to verify their Physics lecturers' TPACK and compared the student evaluation with what the lecturers indicated. Findings indicated that student evaluations and that of the lecturers differed, but there were limitations in the surveys.

In respect of teachers' use of TPACK and their learners' achievement, a literature search involving a variety of sites yielded four studies (Akturk & Saka Ozturk, 2019; Alhababi, 2017; Erdogan & Sahin, 2010; Farrell & Hamed, 2017 and Khine et al., 2017). A positive correlation between student teachers' technological knowledge and their own achievements was reported (Khine et al., 2017) in the United Arab Emirates, though they did not clearly define the meaning of "technology". Akturk, and Saka Ozturk (2019) as well as Erdogan and Sahin (2010) found that learners' performance can be predicted by TPACK. However, in these mentioned studies, student achievement was the pre-service teachers' own achievement.

Furthermore, TPACK requires teachers to have confidence in merging different fields of knowledge effectively. This aspect is linked to beliefs relating to self-efficacy (Ergogan & Sahin 2011) and self-efficacy is substantially linked to student achievement.

Using TPACK correctly makes technology use effective for teachers and learners alike since it promotes teaching and learning (Alhababi, 2017). The researcher did an in-depth study with two teachers and two learners, where the focus was on in-depth student perspective and not necessarily the learners' academic achievement, which the current study seeks to address.

Similarly, a further study into the correlation between teachers' TPACK and the achievement of their learners was recommended (Farrell & Hamed, 2017). These researchers explored the correlation between in-service teachers' learner achievement and TPACK using the Value-added Model (VAM). A VAM score represents the average amount a teacher contributed to the learning growth of learners while controlling for factors that impact the learning growth of learners. These researchers did not find a significant correlation between the TPACK survey or its individual constructs or a teacher's VAM score.

With respect to TPACK and achievement, Erdogan and Sahin (2010) and Khine et al. (2017) studied teacher trainees' TPACK and their own achievement. Alhababi (2017) and Farrell and Hamed (2017) recommended that more research be conducted in the area of TPACK and learner achievement. These prompted the current research to explore grade 11 learners' achievement in electricity and their physics teachers' TPACK.

Theoretical Framework

Mishra and Koehler (2006) initiated the technological, pedagogical, and content knowledge (TPACK) framework which comprises different knowledge domains teachers need to acquire (Koehler et al., 2014). Krauskopf et al., (2012) enlarged this framework since the aspect of knowledge referred to as technological knowledge (TK) should be integrated with the other important teacher knowledge domains, such as pedagogical knowledge

[1] e-TPACK is an adaptive e-learning system that targets the development of teachers' TPACK.

https://doi.org/10.33225/jbse/23.22.282

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

(PK) and content knowledge (CK). Normally, a Venn diagram is used to depict the TPACK, where there are circles representing TK, CK and PK each as the core categories. By combining these categories, three other categories are represented, namely, technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK) and technological content knowledge (TCK). Although different definitions for each of the categories were found (Cox & Graham, 2009), the proposed working definitions for CK, PK and TK in this study are as follows: CK is about subject content that is to be delivered by the teacher and learnt by the learners, PK refers to approaches and processes of delivering the content and TK indicate the knowledge about relevant technologies that can be used in the teaching and learning process. The proposed working definitions for PCK, TPK and TCK are as follows: PCK is the content knowledge relating to the teaching process, TPK is the knowledge of how different technologies may be used in the teaching and learning process, and TCK is the knowledge of how technologies can be used in creating new representations for the content. TPACK refers to the knowledge teachers need to enable the integration of technology when teaching their subject area.

Although the TPACK framework is widely used by researchers and is still being used to address teachers' integration of digital technology in the teaching and learning process, the boundaries between some TPACK domains are fuzzy and lack precision (Angeli & Valanides, 2009). However, it outlines the proficiencies that trained teachers and teacher trainees need to be able to incorporate technology in the modern-day classroom (Kopcha et al., 2014). Kopcha et al. (2014) pointed out that, TPACK has positively affected theory and research in the educational field as well as teacher training and professional development.

Research Questions

The following two research questions were explored:

1. Do teachers' views of their TPACK and Grade 11 learners' views of their teachers' TPACK differ?
2. What is the correlation between Grade 11 learners' achievement in electricity and their Physics teachers' TPACK?

Research Methodology

Design

An exploratory correlational research design was chosen to address the aim of the study namely to explore correlations between different variables. The variables were between the Grade 11 learners' achievement in electricity and their Physics teachers' TPACK, as well as the teachers' self-perception of their TPACK and the Grade 11 learners' views of their teachers' TPACK in 2015.

Sample

The participants were from 42 public schools comprising 42 physics teachers and their corresponding grade 11 learners (*n*=1423) from the Nkangala district in Mpumalanga province of South Africa. The average age of the grade 11 learners who participated in this study is 17 years. The teacher participants' age ranges from 26 years to 41years and above with the majority of the teachers being above 41years of age. The teachers were of a similar qualification background. Gender was not considered for both teachers and learners as it does not feature in the research questions for this research. The research was conducted within four weeks of the third school term. The Nkangala district was purposefully chosen because the learners underperform yearly in the Grade 12 examinations (DBE, 2021). This district is from a low socioeconomic background and is the closest rural district to the first researcher. The final 42 schools were selected based on their high average "yes" scores on a questionnaire dubbed the Learner Confirmatory Questionnaire (LCQ). The LCQ was necessary to find out from learners if their teachers taught the topics, as learners were to be tested on these topics. The findings from the LCQ were only relevant to the selection of schools. The 42 schools were all quintile one schools and were deemed to have the same socio-economic background. There are five categories of schools in the South African education department, referred to as quintile one to quintile five schools. Quintile one schools are the least resourced and quintile five are the most resourced schools.

All participants gave consent and Ethical clearance was granted by Unisa's research ethics review committee Ref: 001/JKK/2014

https://doi.org/10.33225/jbse/23.22.282

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

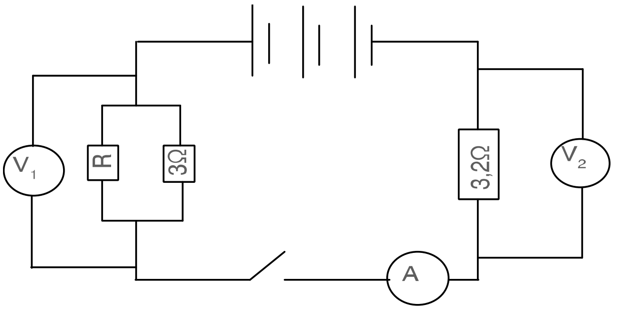
Instruments

Four instruments were used to provide insights into the research: the LCQ, the LEAT, the T-TPACKQ and the LC-T-TPACKQ.

Learner Electricity Achievement Test

The researchers developed the LEAT test using past Physics examination question papers, the Grade 11 text-books pre-scribed as well as the Curriculum and Assessment Policy Statement (CAPS) (DBE, 2011). LEAT was used to collect data on learner achievement in electricity. This is to help answer research question 2 which seeks to the correlation between Grade 11 learners' achievement in electricity and their Physics teachers' TPACK. In question one of the LEAT, the learners had to provide one word for a description, for example, one word for "an area where a charged object experiences a force". In question two, 6 multiple questions were asked for 2 marks each making a total of 12 marks, while question three was about calculating energy cost and providing ways of saving electricity. The first part of question four was on finding the correlation between the current passing through and the potential difference across a resistor. The learners were required to use the dependent and independent variables to find the slope of the graph, which led to the calculation of resistance. The second part of question four is presented below.

4.2 The battery in the circuit below has an EMF of 20V.



The ammeter reads 4A when the switch is closed.

4.2	(a)	Find the total resistance of the above circuit.	(3)
	(b)	Find the reading on voltmeter V_1 with the switch closed.	(6)
	(c)	Find the magnitude of the resistance of resistor R.	(7)

The LEAT counted 60 marks and the time allocated for writing the test was 1 hour and 30 minutes. All learners managed to finish in time.

Learner Confirmatory Questionnaire

The CAPS document (DBE, 2011) subdivides the topic of electricity into 21 sections. The LCQ was designed to find out from learners if they had been taught all these sections by their teachers. Structured closed-ended questions were used, and the learners had to respond "yes" or "no" to questions about whether they had been taught the 21 sections of the topic.

Researchers testing learners with tests developed by themselves (in this case, the LEAT) must find out if the learners were provided with the opportunity to learn in other words whether learners were taught the topics to be tested (Anderson, 2004). The researchers, therefore, used the LCQ to obtain information on whether the topics to be tested in the LEAT had been taught to the learners or not. Schools with a 75% upwards average "yes" score were selected to participate in the study since their learners were deemed to have been taught the topics to be tested in the LEAT. The findings from the LCQ are not relevant for the purpose of this paper and will not be discussed further.

https://doi.org/10.33225/jbse/23.22.282

ISSN 1648–3898 /Print/
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Teacher Technological, Pedagogical and Content Knowledge Questionnaire

A survey instrument was developed to assess teacher trainees' knowledge of teaching and technology (Schmidt et al., 2009). This instrument has been used widely, and its content validity, construct validity and criterion validity have been established (Krauskopt & Forsell, 2018). The instrument guided the development of the T-TPACKQ as we adapted it to our study.

The T-TPACKQ comprised two sections. Section A was to collect data on the teachers' age, gender, qualifications, subject specialisation, and teaching experience. Section B consisted of 27 questions; the teachers had to evaluate each question using a 6-point Likert Scale. They had to indicate "6" if they strongly agreed, ''5" agreed, ''4" slightly agreed, ''3" slightly disagreed, ''2" disagreed, and "1" if they strongly disagreed, in the different TPACK constructs. The teachers had to give reasons for their answers in the spaces provided. The initial 47 questions were reduced to 27 because, in the original instrument, subjects like Mathematics, Geography, Science and Life Sciences were included in the section Content Knowledge (CK). There were three similar statements in each of these subjects and therefore the current questionnaire was adapted to Physics alone and all other subjects were deleted. The T-TPACKQ was the teachers' own report of their TPACK and therefore needed some level of verification.

Learner Questionnaire to Confirm the Technological, Pedagogical, and Content Knowledge for teachers

The LC-T-TPACKQ was similar to the T-TPACKQ. The learners were asked to evaluate their teachers' TPACK since they are at the receiving end of the teachers' teaching. The LC-T-TPACKQ also had two parts. Section A was made up of items intended to elicit learners' biographic data, such as learner and school codes, age, and gender. Section B was made up of items on a 6-point Likert scale, just like Section B of the T-TPACKQ. The items in the LC-T-TPACKQ were constructed in such a way that the learners had to confirm or reject their teachers' responses on the T-TPACKQ. They were designed to elicit the learners' perception of their teacher's technology usage when teaching sections of electricity.

Some of the items in the teacher questionnaire were deleted for the learners because they were found to be inappropriate for them to answer. Items 1, 2, 5, 8, 14, 20, 21, 22, 24 and 25 as they appeared in the T-TPACKQ were deleted for the learners in the LC-T-TPACKQ. An example is: "I know how to solve my own technical problems." A learner cannot make a judgement on this statement and the item was therefore excluded. Some of the items left for the learners to respond include the following: "My Physics teacher keeps up with technologies and My Physics teacher has sufficient knowledge of physics."

As a consequence, part two of the LC-T-TPACKQ had 17 items and not 27 items like the T-TPACKQ. Other changes were, for example, that in the T-TPACKQ, one statement is: "I frequently play around with the technology." This statement was changed in the LC-T-TPACKQ to: "My Physics teacher keeps up with technologies."

Validity of Instruments

The validity of the LEAT ensured that the test covered the subtopics in electricity as prescribed in the South African CAPS curriculum (DBE, 2011). The test was validated by two Physics subject facilitators and three experienced departmental heads of high schools with respect to the content and scope for Grade 11.

It was necessary to ascertain if the questions in the T-TPACKQ would measure exactly what they were meant to measure, checking if the language used was at the right level for the supposed respondents. Hence, five Physics teachers were requested to vet the instrument. Other researchers (Archambault & Barnett, 2010; Lee & Tsai, 2010; Koh et al., 2013, and Sahin, 2011), have validated the TPACK framework and all of them modified and used the Schmidt et al. (2009) questionnaire.

Since the LC-T-TPACKQ was a modification of another questionnaire, it had to be vetted. It was piloted with 5 Physics teachers and 53 of their learners. They vetted the instrument to check if the language was appropriate for the respondents and if it measured what it was meant to measure. The teachers and their learners agreed with all the items in the LC-T-TPACKQ when they vetted it.

https://doi.org/10.33225/jbse/23.22.282

Reliability of Instruments

The reliability of the LEAT was calculated using the Spearman–Brown formula after a pilot sample of 53 learners in Grade 12 had written the test twice within two weeks. Using SPSS version 23, the marks obtained from the pilot testing were used to calculate the Spearman correlation coefficient as .73. The Spearman–Brown formula $R = 2r (1 + r)^{-1}$ was used, and the reliability was established as .84.

The reliability of T-TPACKQ, LC-T-TPACKQ and LCQ was calculated to determine coefficient alpha (α) using SPSS (Blumberg, et al., 2008). The alpha (α) coefficient was T-TPACKQ = .93, LC-T-TPACKQ = .89 and LCQ = .86 respectively.

Data Collection

Two instruments, LCQ and the LEAT were administered to all the participating schools after the teachers had taught the topic of electricity. The other two instruments T-TPACKQ and the LC-T-TPACKQ were administered a week after the participants had completed the first two instruments.

Data Analysis

LEAT

Each LEAT was marked and a mark out of 60 was captured individually.

T-TPACKQ

Two or more question items on each of the TK, CK, PK and TPK constructs were included in the T-TPACKQ. With respect to the constructs with more than one question, the averages of these questions were calculated using SPSS and used as the responses to those constructs. In this way, the 27 questions were reduced to 7.

Questions 23, 24, 25, 26 and 27 represent the TPACK construct questions. In these questions, the teachers had to indicate if they could teach lessons (Physics) that appropriately combined technologies and teaching approaches. These questions are then averaged using SPSS to reflect the teachers' TPACK as recommended by Schmidt et al. (2009).

LC-T-TPACKQ

The 17 questions in this questionnaire were coded in SPSS. As in the previous questionnaire, questions related to the same construct were put together since the modal responses were used as the responses to those constructs for the learners because of the number of learners. The responses were averaged using SPSS for the constructs with multiple questions. The 17 questions were therefore reduced to 7.

Research Results

Physics Teachers' and their Learners' Perspective on the Seven Constructs of TPACK

T-TPACKQ

Of the 42 teacher participants, the distributions of their responses on questions 23 to 27 with respect to the Likert scale are shown in Table 1. These responses were converted to percentages as well in the table.

https://doi.org/10.33225/jbse/23.22.282

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 1
Teachers' Responses to Questions 23,24, 25,26 and 27 on the T-TPACKQ

	Likert scale	Number of teachers					Percentage (%)
		Q23	Q24	Q25	Q26	Q27	
1	Strongly disagree	2	1	3	2	1	4.3
2	Disagree	3	5	2	3	3	7.6
3	Slightly disagree	3	3	8	2	4	9.5
4	Slightly agree	19	11	11	23	15	37.6
5	Agree	10	18	14	9	14	31.0
6	Strongly agree	5	4	4	3	5	10.0
Total		42	42	42	42	42	100.0

Spearman's correlation between the TPACK constructs against the Physics teachers' TPACK is presented (see Table 2).

Table 2
Correlation between the Constructs and TPACK in the T-TPACKQ for the Teachers

Variables	TeacherTK	TeacherTPK	TeacherTCK	TeacherPK	TeacherPCK	TeacherCK
Teachers' TPACK	.612 **	.833**	.614**	.539**	.400**	.310*

*. Significance at .05 (2-tailed)
**. Significance at .01 (2-tailed)

A positive statistically significant correlation existed between the teachers' TPACK and the different constructs. It is evident that the TPACK correlated strongly with constructs containing technology.

LC-T-TPACKQ

The constructs TPACK, TPK, TK, PK and CK had more than one question. Table 3 shows Spearman's correlation of the learners' responses in the LC-T-TPACKQ regarding their teachers' CK, TK, PCK, PK, TCK and TPK against TPACK. A positive statistically significant correlation was found between the teachers' TPACK constructs and their TPACK from the learners' perspective.

Table 3
Correlation between Constructs and TPACK in the LC-T-TPACKQ for Their Teachers

	Learners' Reported					
	TK	TPK	TCK	PK	PCK	CK
Learners' Reported TPACK	.406**	.589**	.391*	.309*	.443**	.730**

*. Significance at .05 (2-tailed)
**. Significance at .01 (2-tailed)

The independent sample t-test responses in the T-TPACKQ and the LC-T-TPACKQ constructs of the TPACK framework (seven in total) at a 95% confidence interval (α = .05) were used to determine if the Grade 11 learners' view and their teachers' self-perception differed in the TPACK questionnaires. The questions and their corresponding codes, the averages, and the significance (p) values are summarised (see Table 4).

https://doi.org/10.33225/jbse/23.22.282

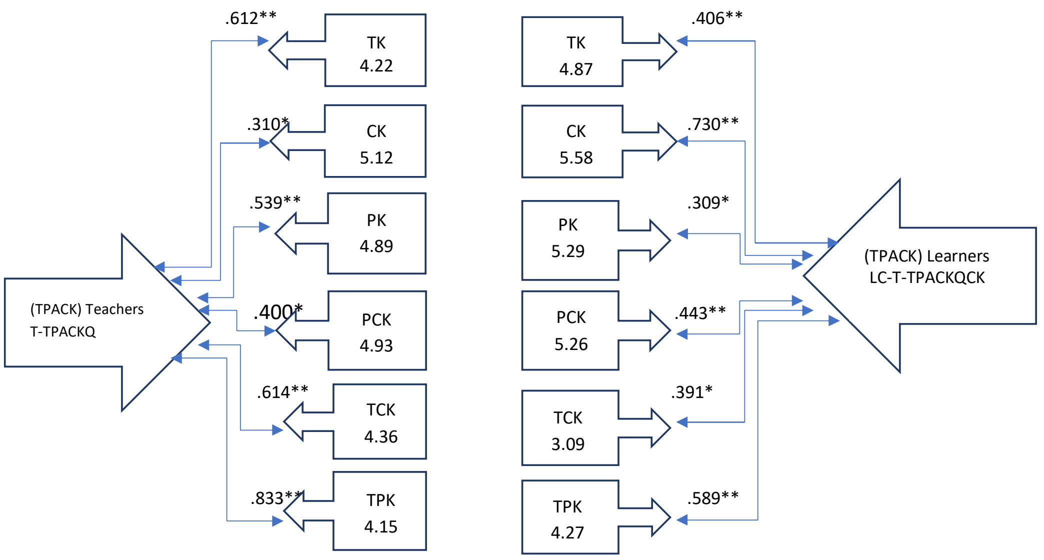
Table 4
t-Test Comparison of the Responses from the T-TPACKQ and LC-T-TPACKQ

Questions	Codes	Mean		Significance (p) value (2-tailed)
		Learners	Teachers	
1	TK	4.87	4.23	.004*
2	CK	5.58	5.12	.001*
3	PK	5.29	4.89	.005*
4	PCK	5.26	4.93	.038*
5	TCK	3.10	4.36	.001*
6	TPK	4.27	4.15	611
7	TCPK	5.33	4.17	.001*

* Statistically significant difference

The findings from the 6-point Likert scale showed that both the learners' and teachers' averages were more than 4, but TCK was less than 4 from learners' responses. However, the *p* values of questions on all the TPACK constructs were below (.05) significance, except in the case of TPK. Therefore, a statistically significant difference was established between the mean values on the LC-T-TPACKQ and those on the T-TPACKQ. This implies that the mean value difference was not due to chance, but the significance *p* value was found to be .611 on the items related to TPK, which was greater than .05. Therefore, the learners' responses regarding TPK in the LC-T-TPACKQ were not significantly different from the TPK-related responses in the T-TPACKQ. Questions 23, 24, 25, 26 and 27 in the T-TPACKQ averaged as TPACK for teachers and questions 15, 16 and 17 in the LC-TTPACKQ for learners averaged as TPACK for the learner questionnaire. Therefore, a teacher has TPACK if the response to the particular questions' averages (i.e., questions 23, 24, 25, 26 and 27 or 15, 16 and 17) is 4, 5 or 6. The LC-T-TPACKQ and T-TPACKQ are compared closely as they all correlate statistically significantly. The subconstructs are represented in figure 1. The means of the constructs are written together with the t-test correlations for both questionnaires.

Figure 1
Responses on the T-TPACKQ and the LC-TTPACKQ Showing Averages and the t-Test Correlations between TPACK and its Constructs



From table 4, as well as table 5 (group statistics), the LC-T-TPACKQ (M = 5.333) and T-TPACKQ (M = 4.167). These mean values are interpreted as that both teachers and their learners agreed.

https://doi.org/10.33225/jbse/23.22.282

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 5

t-Test of the T-TPACKQ Responses and the LC-T-TPACKQ Responses on TPACK

Group statistics					
	Respondent	*N*	*M*	*SD*	*SEM*
TPACK for both	Learners	42	5.333	0.650	0.100
	Teachers	42	4.167	1.228	0.189

Independent sample t-test

	Learners		Teachers				95%CL	
Variable	*M*	*SD*	*M*	*SD*	*t (82)*	*p*	*LL*	*UP*
Scores	5.33	.65	4.17	1.22	5.44	.002	.74	1.59

M = mean; *SD* = standard deviation; *CL* = confidence interval; *LL* = lower limit; *UL*= upper limit

As indicated in table 5, the independent sample t-test shows that ($p < .05$) at a 95% confidence level (***α*** = .05). This is interpreted as the t-test (with 82 degrees of freedom) was statistically significant.

Correlation between Teachers' TPACK and their Learners' Achievement

The achievement of the learners of a specific teacher was found by calculating the class LEAT average. The teacher's score from the T-TPACKQ was averaged and represented the teacher's TPACK. The 42 Physics teachers' TPACK and their Grade 11 learners' LEAT average scores were correlated using Spearman's correlation. The correlation was significant at $p < .05$ at a 95% confidence level and this means that the probability that this correlation was obtained by chance is less than 5%. A correlation was found between the participating teachers' TPACK and their learners' achievement. However, it was not statistically significant (Spearman's rho (42) = .28, $p = .072$).

Discussion

From table 1, 21.4% of teachers disagreed with questions 23, 24, 25, 26 and 27, which means that they have evaluated that they have no TPACK while the rest (78.6%) indicated that they had TPACK. In analysing the T-TPACKQ, a positive correlation between all the constructs (TPK, TK, TCK, PCK and PK) and the Physics teachers' TPACK was established at a .01 significance level, and this correlation is statistically significant.

A positive statistically significant correlation with the TPACK was found for CK at a .05 significance level as the least correlated. This finding is supported by Lin, Tsai, Chai and Lee, (2013). These researchers conducted their study in Singapore and also found a statistically significant correlation between all the constructs and the teachers' TPACK. However, in a study among 455 trained teachers also in Singapore, Koh et al. (2013) concluded that CK and PCK were not evident.

In analysing the LC-T-TPACKQ, a positive correlation between all the TPACK constructs of the participating teachers' TPACK and their TPACK from their learners' perspective was statistically significant. However, when the Grade 11 learners' perception of their teachers' TPACK and their teachers' self-perception in the TPACK questionnaire were compared, the averages on the LC-T-TPACKQ differed significantly from those on the T-TPACKQ. When Jang and Chang (2016) asked learners to verify their Physics lecturers' TPACK and compared the student evaluation with what the lecturers indicated, they too found a difference between the two groups.

Research suggested that a study into the correlation between learners' achievement and their teachers' TPACK is needed (Farrell & Hamed, 2017), while Jang and Tsai (2012) emphasised it must be in specific subject areas.

https://doi.org/10.33225/jbse/23.22.282

After the topic of electricity had been taught using technology, a correlation between Grade 11 learners' achievement and their Physics teachers' TPACK in electricity was established. However, this correlation was not statistically significant, a result which confirms the assertion of Khine et al. (2017) that, technology usage alone is inadequate to yield the required outcomes in learners' achievement.

Physics teachers have an exaggerated view of their use of technology (Jang & Chang, 2016) but were not supported in this study. The results indicate the opposite in that learners rated their teachers higher than the teachers rated themselves. This finding can be seen in the mean values shown in table 4. Although TPACK can significantly predict student success, Erdogan and Sahin (2010) used trainee teachers' own achievement and did not provide evidence of the effect of TPACK on their learners' achievement. Furthermore, no significant correlation was found between the TPACK survey and the teachers' VAM score (Farrell & Hamed, 2017), which is supported in the current study.

Limitations

No generalisations can be made since this is an exploratory study in one district of the country.

Conclusion and Implications

The TPACK framework is a complex interaction between the different types of knowledge domains. The interaction of these knowledge domains is needed to integrate technology successfully into teaching.

Results from both teachers and learners' questionnaires show positive correlations between these knowledge domains with TPACK. New insights have been obtained by exploring Physics teachers' TPACK and their learners' achievement in electricity. First, there is a statistically significant difference between teachers' view of their own TPACK and their learners' view of their TPACK, as learners rated their teachers higher than the teachers rated themselves. This differs from the previous research results and therefore invites further research in this area to help provide conclusive results. Secondly, even though there was a positive correlation between the learners' achievement and their teachers' TPACK, the correlation was not statistically significant. Further research is therefore needed as the current study did not prescribe any specific technology during the teaching of electricity.

As the TPACK paradigm offers a framework for both in-service and pre-service teachers to integrate technology into the classroom, it also provides the opportunity for metacognition with regard to these teachers' own learning and professional development. The findings have further expanded the TPACK research, as these findings can influence investments into the nature of teachers' professional development. This study provided answers with regard to the influence of teachers' TPACK and their learners' performance as well as how the teachers 'evaluate their own use of technology and therefore the future use of technology in education in South Africa, Africa and the world over.

Declaration of Interest

The authors declare no competing interest.

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Received: *September 18, 2022* Revised: *January 31, 2023* Accepted: *March 20, 2023*

Cite as: Kotoka, J. K., & Kriek, J. (2023). Exploring physics teachers' technological, pedagogical and content knowledge and their learners' achievement in electricity. *Journal of Baltic Science Education*, *22*(2), 282-293. https://doi.org/10.33225/jbse/23.22.282

Jonas Kwadzo Kotoka PhD Student in the Department of Physics, Eureka Building, Science Campus, Florida, South Africa.
E-mail: kotokajk@gmail.com
ORCID: https://orcid.org/0000-0001-6835-5738

Jeanne Kriek *(Corresponding author)* MSc, PhD, Professor, University of South Africa, Department of Physics, Eureka Building, Science Campus, Florida, South Africa.
E-mail: kriekj@unisa.ac.za
Website: https://sites.google.com/site/jeannekriek
ORCID: https://orcid.org/0000-0001-6248-4563