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Science Teacher's Technological Knowledge and Application in the Teaching and Learning of Science

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Abstract
This study aims to assess the technological pedagogical content knowledge of science teachers in Kebbi State, Nigeria. Four research questions and three objectives served as the foundation for this study. A mixed-method design was used. Purposively chosen, 50 science teachers were included in the sample (45 men and 5 women). The science teacher questionnaire and the science teacher classroom observation checklist were the two devices utilized to collect the data. Descriptive statistical techniques, such as means and standard deviations, as well as inferential statistics, such as Pearson product moments, were used to analyze the data. Technology integration in the classroom has a significant impact on how science is taught and learned. It is therefore recommended, among other things, that science teachers acquaint themselves with technical skills to use ICT integration effectively in the teaching process.
Keywords*: Science teachers, Technology integration Technological resources*

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I. Introduction

Shulman's approach introduces an innovative shift in classroom instructional strategies (Johnson et al., 2014). Mishra and Koehler (2006) introduced a new category of teacher knowledge called Technical Awareness, which is made up of technical knowledge (TK), technological pedagogical knowledge (TPK), and technological content knowledge (TCK), to supplement Shulman's model of teacher knowledge. To highlight the integrated character of the components, the overall "package," and for pronunciation convenience, the resulting model, TPCK, was renamed TPACK (Thompson & Mishra, 2007).

Integration of technology in education has increasingly become an important concern in education, not only in developed countries but in developing countries as well. Technological pedagogical content knowledge (TPACK) is a theory that was developed to explain the set of knowledge that teachers need to teach effectively using technology (McGraw-Hill, 2019). TPACK plays an important role in science teaching and learning processes.

TPACK plays an important role in science teaching and learning processes.The integration of technological pedagogical content knowledge (TPACK) into classroom instruction has been a challenge for science teachers. The TPACK framework represents the knowledge needed by teachers to bring together technological knowledge, pedagogical knowledge, and content knowledge to integrate information and communication technology (ICT) into teaching-learning processes.

Statement of the problem

In the sphere of education, technology use—along with its goods and applications—is unavoidable (Sensoy & Yildirim, 2018). The value of incorporating technology into classroom learning is acknowledged throughout the globe today. To successfully integrate technology into the teaching and learning process, science teachers must acquire specialized knowledge of technological pedagogical content (Abbitt, 2011a; Harris & Hofer, 2011; Koehler & Mishra, 2005; Mishra & Koehler, 2006; Otrel-Cass et al., 2010).

As a result, while delivering specific subjects, science teachers ought to be able to select the right technology to employ in conjunction with the right pedagogical strategy. Science teachers must combine their technological knowledge, content knowledge, and pedagogical knowledge to teach students who are technology literate. They must also use these skills appropriately and successfully in their classroom activities (Mishra & Koehler, 2006; Koehler & Mishra, 2008; Niess, 2008; Angeli & Valanides, 2009). Furthermore, several studies have found in the literature that using technology in the classroom increases student success (Tuysuz, 2010; Gonen, Kocakaya, & Inan, 2006).

Despite all of technology's benefits, a lot of scientific teachers are not confident in their ability to teach science in technologically advanced environments. Despite government efforts to provide computers and the recent establishment of computer laboratories in most secondary schools, the main obstacle to technology integration in teaching is science teachers' lack of knowledge about how to integrate technology in instruction (Agyei, 2012; Agyei & Voogt, 2011a, b). The purpose of the study is to evaluate science teachers' technical knowledge and its application in teaching and learning science in Kebbi State, Nigeria, as there has been little research on TPACK in that country

Objectives of the study

1. To examine science teachers level of Technological Knowledge
2. To determine the extent to which science teachers use technologies in teaching and learning science
3. To identify the challenges, face by science teachers in using technology for effective teaching and learning of science

Research questions

1. What is the level of science teachers' technological knowledge?
2. To what extent do teachers use technologies in teaching and learning science?
3. What is the adequacy of technological resources in the science department be describe?
4. What is the relationship between adequacy of technological resources and their uses in teaching and learning science?

II. Review Of Related Literature

The field of educational research was introduced to Technological Pedagogical Content Knowledge (TPCK) as a theoretical framework for comprehending teacher knowledge necessary for technology integration. TPACK is used to evaluate teachers' proficiency in incorporating technologies into their lessons, which aids in the development of their topic knowledge, pedagogical knowledge, and technological abilities throughout their careers. Aslam and others, 2021). Koehler and Mishra (2008) assert that the three fundamental elements of effective technology-based instruction are pedagogy, content, and technology, along with the connections between them as illustrated by the TPCK frame.

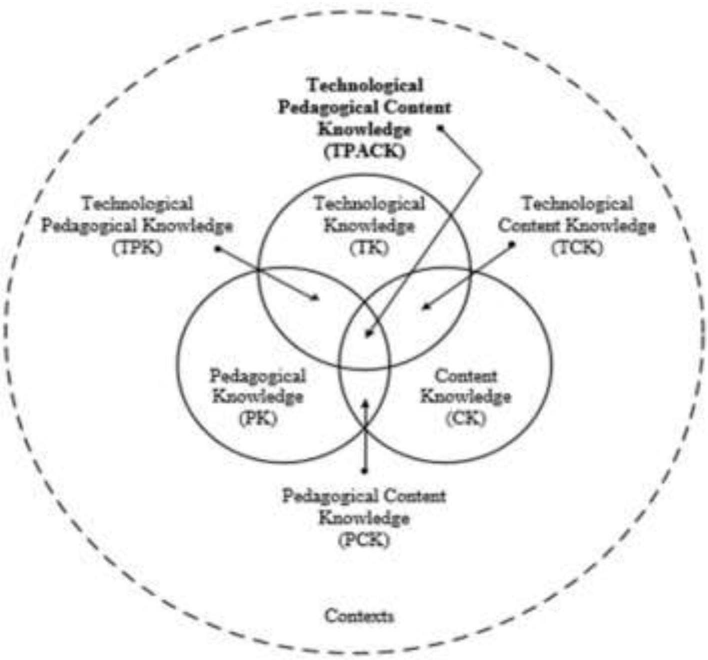

Fig. 1: Framework of TPCK: (Koehler & Mishra, 2008).

Teachers of science rely heavily on TPACK to help mold the next generation of scientists. According to Koehler et al. (2014), TPCK is a prominent framework that helps teachers identify the competencies they need to integrate technology into their lessons. Several studies have demonstrated that to deliver lessons effectively, attention still needs to be paid to the use of TPACK in the classroom (Graham et al., 2009; Horzum, 2013; Joseline, 2021).

We pay special attention to the knowledge domains in which technology is involved: TK, TCK, TPK, and TPCK. This is because the study explains and evaluates science teachers' technical knowledge and application in the teaching and learning of science. Graham et al. (2009) focused on four framework constructs (TPCK, TPK, TCK, and TK) in order to assess the TPACK confidence of in-service science teachers. Fifteen teachers were evaluated on these constructs both before and after they took part in a professional development program. The participants had to have more confidence in TK, TPK, TPCK, and TCK, in decreasing order, at the beginning and end of the program, according to their demands. They stated that their research demonstrated that before developing the other constructs, one had to possess a foundational understanding of technology.

III. Methodology

The Study Area

Argungu and its environs lie in the North-Western part of Kebbi State, in the North-Western part of Nigeria. The location covered by the study is Argungu metropolis. Its geographical coordinates are 12° 44'23''N and longitude 4°' 30'54'' E. The city is the seat of the Argungu Emirate, a traditional state. According to the population census of 2007, Argungu had an estimated population of 47,064. Argungu is a major agricultural center for the area, with key crops including rice, millet, and sorghum. Argungu also hosts an annual international fishing festival. The vegetation of the study area is a sub-climate of the original rainforest, having been virtually cleared due to development. Argungu receives a mean temperature of 260°C and can rise to 400°C at the peak of the hot season from March to July.

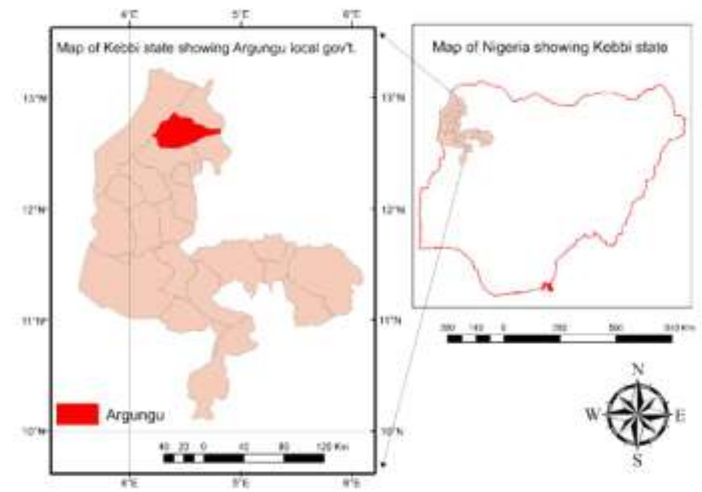

Fig 2. Map of Kebbi State, showing the location of Argungu.

Research design

The study employed a mixed-methods approach with a convergent parallel design, including both survey and case study methodologies. A questionnaire was used as part of the survey technique to get science teachers' viewpoints. Classroom observation was used in the case study technique to gain a thorough understanding of the tasks that science teachers complete in their classes. It was discovered that the best strategies for the study to comprehend the subject under investigation were surveys and case studies.

Population of the study

The population for the study comprised all science teachers of Adamu Augie college of education Argungu. The average teaching experience of the respondents was approximately 12 years ranging from 1 year to 30 years of teaching various field of science in the college. With different educational qualifications ranged from Bachelor of science to PhD in science.

Sample and sampling technique

A total of 50 science teachers (45 males and 5 females) for the quantitative part and three science teachers (2 males and 1 female) for the qualitative part were purposefully sampled based on the availability of technological tools in their department. and most of the participants had their computers, and they used Facebook, WhatsApp, Instagram, and e-mails regularly.

Instruments

In this study, two data collection instruments were used. Science teacher questionnaire and science teacher classroom observation checklist. Both the science teacher questionnaire and the science teacher classroom observation checklist were adopted. The science teacher questionnaire contains two sections, A and B. Section A asked for information from the respondents on their demographic factors like gender, academic qualification, teaching experience, and levels they were teaching. Section B contained 30 items and was rated using 4-point Likert-type scales. The science teacher classroom observation checklist measuredscience teacher usage of digital technologies in teaching. The science teacher questionnaire and science teacher classroom observation checklist were validated by four experts in science education and instructional technology.

Method of Data Analysis

The collected data was analyzed using descriptive statistical methods (including means and standard deviations), and Pearson product-moment was also used.

IV. Results

Demographic Characteristics

The demographic characteristics of teachers involved in this research include gender, age, educational attainment, and teaching experience. A total of 50 science teachers responded to the questionnaire. The details of the distribution of the teachers' biographical data are presented in Table 1. The majority of the science teachers who participated in the study were males (90.0%). Females constituted only 10% of the science teachers surveyed. Approximately 78% of all respondents were above 41 years of age, and about 36% of the science teachers had obtained degrees beyond the bachelor's level. The majority (64%) of the participants had acquired their first degree in their respective science and science education areas.

Table 1: Demographic characteristics of participants. (N = 50)

Variable	N	%
Gender		
Male	45	90
Female	5	10
Age		
30-40	11	22
41-50	34	68
51-60	5	10
61 above	0	0
Educational attainment		
PhD	4	8
M.sc	6	12
M.Ed.	8	16
1st degree (BSc)	24	48
1st degree (B.S.Ed.)	8	16
Teaching Experience		
<1year	4	8
1-2 years	11	22
3-5 years	9	18
6-10 years	10	20
11-15 years	7	14
Above 15 years	9	18

The majority (52%) of the teachers had been teaching science for more than 10 years, and 40% had science teaching experience of less than one to five years.

Level of science teachers' technological knowledge

Data was gathered from science teachers to find out the level of technological knowledge used in teaching and learning science. The TPACK model was used in this research, but we particularly focus on the knowledge areas in which technology is involved: TK, TCK, TPK, and TPCK. Teachers' responses were recorded, and the mean scores and standard deviations for the various constructs involved are provided in Tables 2, 3, 4, and 5.

Technological Knowledge

In this analysis, the four-point Likert scale was considered. The average mean score was used to define the level of technological knowledge that science teachers used in teaching and learning science. Table 2 presents the mean scores and standard deviation on technological knowledge.

Table 2: Mean and standard deviation scores on science teachers' technological knowledge

		N	Mean	Std. Deviation
1.	I know how to solve my own technical problems	50	3.60	.808
2.	I keep up with important new technologies	50	3.46	.734
3.	I know about a lot of different technologies	50	3.52	.646
4.	I have the technical skills I need to use technologies	50	3.56	.611
5.	I have had sufficient opportunities to work with a range of technologies	50	3.26	.803
6.	I can learn to use new software easily on my own	50	3.32	.794
	Average mean		**3.45**	

Table 2 shows the level of science teacher technology knowledge (TK), where the highest mean score falls on item 1 (M = 3.60) and the lowest mean score on item 5 (M = 3.26), as well as the average mean score (M = 3.45). Both the highest, lowest, and average mean scores for this component lie within the agreed level of 3 points. As the average mean score (M = 3.45) is above the 3.00 point, this indicates that science teachers have a moderate level of technological knowledge. Table 3 presents the mean scores and standard deviation for technological content knowledge.

Table 3: Mean scores and Standard Deviation on Technological Content Knowledge.

		N	Mean	Std. Deviation
7.	I know about technologies that I can use for teaching specific concepts in my subject matter	50	3.24	.981
8.	I know how my subject matter can be represented by the application of technology	50	3.36	.802
9.	I know about technologies that I can use for enhancing the understanding of specific concepts in my subject matter	50	3.48	.814
10.	I can use technological representations (i.e. multimedia, visual demonstrations, etc.) to demonstrate specific concepts in my subject matter	50	3.44	.760
11.	I can use technology to make students observe phenomenon that would otherwise be difficult to observe in my subject matter	50	3.56	.611
12.	I can use technology to create and manipulate models of scientific phenomenon (e.g. animations, modelling, etc)	50	3.16	.912
	Average mean		**3.37**	

Table 3 revealed the mean scores of the science teachers concerning their level of technological content knowledge. The mean scores show that all the science teachers generally agreed that they had attained a certain level of technological content knowledge. This is because the mean scores correspond to the agreed-upon level on the four-point Likert scale used. The highest mean score falls on item 11 (M = 3.56), the lowest mean score is on item 12 (M = 3.16), and the average mean score is 3.37. It means that science teachers have a moderate level of knowledge of technology content. Table 4 presents the mean scores and standard deviations of science teachers. Technological and pedagogical knowledge.

Table 4: Mean Scores and Standard Deviation on Science Teacher Technological Pedagogical Knowledge

		N	Mean	Std. Deviation
13.	I can choose technologies that enhance the teaching approaches for a lesson	50	3.42	.642
14.	I can choose technologies that enhance students learning of a concept	50	3.46	.613
15.	I can choose technologies that are appropriate for my teaching	50	3.46	.613
16.	I can apply technologies to different teaching activities	50	3.20	.728
17.	I can effectively manage a technology-rich classroom	50	3.04	.832
18.	I can use technology to help assess student learning	50	3.10	.735
	Average Mean		**3.28**	

Table 4 shows the level of science teacher technological pedagogical knowledge, where the highest mean score falls on items 14 and 15 (M = 3.46), respectively, and the lowest mean score on item 17 (M = 3.04), as well as the average mean score (M = 3.28). Both the highest, lowest, and average mean scores for this component lie within the agreed level of 3 points. As the average mean score is used to determine the level of knowledge in this research, this indicates that science teachers have attained a low level of technological and pedagogical knowledge. Table 5 presents the mean scores and standard deviation on technological pedagogical content knowledge.

Table 5: Mean scores and Standard Deviation on Technological pedagogical content knowledge

		N	Mean	Std. Deviation
19.	I can teach lessons that appropriately combine my subject matter, technologies, and teaching approaches	50	3.34	.717
20.	I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn	50	3.54	.676
21.	I can use strategies that combine content, technologies, and teaching approaches in my classroom	50	3.44	.541
22.	I can use technology to facilitate scientific inquiry in the classroom	50	3.52	.544
	Average mean		**3.46**	

Table 5 shows the results on the level of technological pedagogical content knowledge. the science teacher attained. The highest mean score falls on item 20 (M = 3.54), the lowest mean score is on item 19 (M = 3.34), and the average mean score is 3.46. It means that science teachers have a moderate level of knowledge of technology content.

Utilization of technologies in teaching and learning science

The science teachers were asked to rate their usage of technologies in teaching and learning science. The responses were ranked in a Likert scale format with "not at all" = 1, less often; = 2, often= 3, and very very often" = 4. The responses are summarized in Table 6.

Table 6: Mean and standard deviation on the extent science teachers utilize technologies in teaching and learning of science

	N	Mean	Std. Deviation
I can use technological representations (i.e. multimedia, visual demonstrations, etc.) to demonstrate specific concepts in my subject matter	50	2.76	1.188
I can use various types of technologies to deliver the content of my subject matter	50	2.90	1.074
I can use technology to make students observe phenomenon that would otherwise be difficult to observe in my subject matter	50	2.94	.956
I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn	50	2.72	.991
I can use technology to create and manipulate models of scientific phenomenon (e.g. animations, modelling, etc)	50	2.78	1.055
I can choose technologies that enhance the teaching approaches for a lesson	50	2.80	1.107
I can choose technologies that enhance students learning of a concept	50	2.72	1.070
I can choose technologies that are appropriate in my teaching	50	2.72	.970
I can apply technologies to different teaching activities	50	2.42	1.052
I can use technology to help assess students learning	50	2.68	1.115
I can use technology to actively engage students in teaching and learning	50	2.52	.995
I can teach lessons that appropriately combine my subject matter, technologies, and teaching approaches	50	2.64	1.174
I can choose technologies that enhance the understanding of the content for a lesson	50	2.22	1.148
I can use technology to facilitate scientific inquiry in the classroom	50	2.16	1.131
I can use technology to create effective representations of content that departs from textbook approaches	50	1.84	.955
I can use technology to create and manipulate models of scientific phenomenon (e.g. animations, modelling, etc)	50	2.24	1.080
Average mean		**2.40**	

The results in Table 6 show that the science teachers could not use technology to create effective representations of content that depart from textbook approaches, with a mean score of M = 1.84. The table revealed that almost all the mean scores are within less frequent intervals (M = 2.76, M = 2.72, M = 2.78, M = 2.78) in the four-point Likert scale used. Two of the items, "I can use various types of technologies to deliver the content of my subject matter" (M = 2.90) and "I can use technology to make students observe phenomena that would otherwise be difficult to observe in my subject matter" (M = 2.94), were close to the value of often using technologies in the teaching and learning of science. The average mean value (M = 2.40) indicates that science teachers less often make use of technologies in the teaching and learning of science.

Adequacy of Technological Resources

About 14 technological resources and their mean and standard deviation scores were presented in Table 7. Given the four-point Likert scale, the questionnaire was interpreted using the following real limit numbers: 3.50–4.00 = Very adequate; 2.50–3.49 = Adequate; 1.50–2.49 = Fairly adequate; and 0.50–1.49 = Not adequate.

Table 7 Mean and standard deviation on the Adequacy of Technological Resources

Technological resource	Mean	Std. Deviation
Computer	2.66	.479
Projector	1.50	.863
Speaker	2.26	.828
Social media service	2.34	.848
Smartphone	2.20	.808
Internet connection	1.32	.471
Learning management	1.68	.621
Tablet	1.66	.688
Printer	2.44	.861
Scanner	2.08	.853
Digital learning	1.14	.351
Adaptive learning	1.00	.000
Video gaming facilities	1.24	.431
Video conferencing	1.00	.000
Average mean	**1.80**	

Table 7 presents science teacher's responses to the adequacy of technological resources which revealed that only computer is adequate to all schools under study having a mean score of 2.66. majority of the technological resources like Projector, Speaker, Tablet, Smartphone, Social media service, Learning management, Printer, Scanner, were fairly adequate having mean scores between 1.50 – 2.44. Table 7 also shows that some technological resources like Internet connection, Digital learning, Adaptive learning, Video gaming facilities and Video conferencing having a mean scores between 1.00- 1.32 were not adequate in all the schools under study. Even though the average mean score 1.80 indicates that technological resources were fairly adequate in the schools under study.

Correlations between the adequacy of technological resources and their uses in teaching and learning science

Pearson's correlation coefficient was used for this analysis, and the result is presented in Table 8.

Table 8: Correlation results for the adequacy of technological resources and their**uses in teaching and learning science**

		Adequacy	use
Adequacy	Pearson Correlation	1	.365**
	Sig. (1-tailed)		.005
	N	50	50
use	Pearson Correlation	.365**	1
	Sig. (1-tailed)	.005	
	N	50	50
**. Correlation is significant at the 0.01 level (1-tailed).			

Table 8: It was observed from Table 8 that there are statistically significant correlations between theadequacy of technological resources and theiruses in teaching and learning science. The Pearson correlation shows a positive value (r) of 0.356, which indicates that both variables move in the same direction.

V. Discussion

The adoption of technology by science teachers is considered a measure of technology integration. Technology integration provides opportunities for science teachers to enhance their professional knowledge and skills to arouse students' interest in learning and their performance in general. It was found in the study that the overall mean scores on the four sub-scales: technological knowledge (M = 3.45), technological content knowledge (M = 3.37), technological pedagogical knowledge (M = 3.28), and technological pedagogical content knowledge (M = 3.46), fell within the agreed level, which represented a considerable presence of a moderate level of technological knowledge. This finding is in agreement with the research of Akturk and Ozturk (2019), which revealed teachers had moderate knowledge of TPACK at the TK, TCK, TPK, and TPCK levels. The results contradict those of Santos & Castro (2021), who said that pre-service teachers have strong subject-matter expertise in all areas of TPACK based on the general mean. Tanak (2018) also found that teachers scored lowest on the integrated TPACK dimension, while they scored highest on individual technological knowledge. The findings of this study found that science teachers less often utilize technologies in the teaching and learning of science. Although two out of the 16 statements were close to the value of often using technologies in the teaching and learning of science, this indicates that the technologies in teaching and learning scienceare less often utilized.

Many research studies have confirmed that there are several factors affecting the use of technology, such as gender, socioeconomic status, and age. Recent studies about the effect of age on attitude towards computers have shown that younger people tend to have more positive attitudes towards the use of computers than their older peers (Christensen & Knezek, 2006; Meelissen, 2008). This indicates that younger teachers are more likely to use technology in instruction than older ones. The less often use of technology could be because the majority of the respondents were within the age range of 41–50 years (see Participants demographic characteristics section). The use of appropriate technological tools can also help the student become equipped for the subject being taught.

Santos (2017) confirmed in her study that one of the top skills of students is using technology as a tool for learning. Today, younger students are being introduced to the use of computers in their learning, and this helps a lot to fuel their development.

From this study, it was also confirmed that the majority of the technological resources, like projectors, speakers, tablets, smartphones, social media services, learning management, printers, and scanners, were fairly adequate, and some technological resources, like Internet connections, digital learning, adaptive learning, video gaming facilities, and video conferencing, were not adequate in all the schools under study. This finding supports a previous study by Jack and Songo (2020), who reported that there were inadequate ICT resources provided in secondary schools in Jalingo Metropolis, Taraba State. This implies that there would be an inadequate implementation of the science curriculum, which, in turn, could affect the learning as well as the academic performance of the students in the sciences. These technological resources can help students learn how to research topics and concepts that they do not understand or are familiar with. By having an adequate technological resource, students can attend online sessions, listen, and participate in discussions with their teachers and the science community.

The study also found that there are statistically significant relationships between the adequacy of technological resources and their uses in teaching and learning science. The result supports the findings of Jack (2021), who confirmed a highly positive relationship between adequacy and utilization of ICT resources among practicing pre-service science teachers. However, the less often use of technological resources may perhaps be a result of the low adequacy of technological resources, and this is similar to the opinion of Amuko et al. (2015) that effective utilization of ICT resources in secondary schools is also largely dependent upon the availability and adequacy of ICT resources.

VI. Conclusion

The study is purposefully designed toassess science teachers' technological knowledge and its application in teaching and learning science. The study reveals that science teachers have attained a moderate level of technological knowledge to integrate technology into the teaching and learning of science. The cooperating schools in this study showed fairly adequate technological resources. Therefore, this could be one of the causes of science teachers' less frequent use of technologies in the teaching and learning of science. There were positive correlations between the adequacy of technological resources and theiruses in teaching and learning science.

VII. Recommendation

The following recommendations are made in line with the findings of the study:

1. Science teachers should acquaint themselves with technical skills to use ICT integration effectively in the teaching process.
2. The government should provide continuous professional development training to update science teachers' knowledge and develop their skills in the use of technologies in classroom teaching.
3. The government should provide sufficient funds to provide adequate technological resources in schools and arrange some sort of training for science teachers to use ICT integration effectively in the teaching process.

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