INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

Correlation Between Alternative Frameworks and Performance of Physics Pre-Service Teachers in Basic Electronics Content: A Case of a Higher Learning Institution in Lusaka District

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DOI: https://doi.org/10.51583/IJLTEMAS.2026.150700010

Received: 19 June 2026; Accepted: 24 July 2026; Published: 05 August 2026

ABSTRACT

Research in physics education indicates that students do not enter the classroom with blank minds but hold various alternative frameworks about what they are going to learn. Due to their strength and flawed content, alternative frameworks interfere with students' learning of correct physics theories, principles, and concepts, consequently affecting their performance, particularly in challenging areas such as electronics. While this is well-documented internationally, research does not specify the degree of relationship between alternative frameworks and performance of students in any physics topics in the Zambian context. This study sought to determine the correlation between physics pre-service teachers' alternative frameworks and their performance in basic electronics at a higher learning institution in Lusaka District, Zambia. A quantitative approach employing a correlation design and a one-case pre-test post-test control group design was used. The population comprised 191 Bachelor of Science with Education (BSc. Ed) and Bachelor of Education-Secondary (Mathematics and Science) (BEDMAS) pre-service teachers of physics; the sample consisted of 60 participants selected using simple random sampling. A structured questionnaire and a multiple-choice test on basic electronics were used for data collection. Instruments were piloted for validity and a test-retest method was used to check reliability. Data were analysed using descriptive statistics (Pearson's Product Moment Correlation coefficients) and inferential statistics (t-values). The findings revealed Pearson's Product Moment Correlation coefficients of -0.7 and -0.9 (sig at 0.00, 2-tailed) at 99% confidence interval before and after the treatment respectively. The study concluded that there was a strong negative correlation between physics pre-service teachers' alternative frameworks and their performance in basic electronics. The study recommended that physics educators should pay attention to such conceptions and clarify them so that pre-service teachers could develop conceptual understanding of basic electronics before entering the teaching profession.

Keywords: Alternative frameworks, basic electronics, correlation, performance, physics pre-service teachers, Zambia

INTRODUCTION

Background to the Study

Basic electronics has been a challenging section in senior secondary physics in Zambia (Examinations Council of Zambia, 2010). Haambokoma et al. (2002) contended that despite its importance, electronics is rated the most difficult section of the senior secondary school physics syllabus not only for pre-service teachers but also for qualified teachers of physics. Most of them (65%) rate themselves as not confident in teaching electronics and are least comfortable to teach that section (Haambokoma et al., 2002, p. 128). One reason given by teachers of physics for such difficulties is that they do not have adequate knowledge in basic electronics (Haambokoma et al., 2002, p. 129). Many Heads of Science Departments in Zambia agree and suggest that teachers of physics need help in understanding electronics theoretically and practically (Haambokoma et al., 2002, p. 128).

Consequently, learners also find electronics a difficult section to understand in senior secondary physics. Haambokoma et al. (2002, p. 142) added that in the SMASSE study carried out in Kenya in 1999, teachers had

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difficulties teaching and pupils had difficulties learning, among other topics, electronics. In Zambia, pupils advanced some reasons for finding electronics difficult to learn, and one of them was no or unclear explanation from teachers (Haambokoma et al., 2002, p. 142). The reasons advanced by physics educators and learners for finding electronics a very challenging topic could be due to their alternative frameworks in that area.

Alternative frameworks (also referred to in the literature as alternative conceptions or misconceptions) are ideas strongly held by learners that may be significantly different from accepted scientific viewpoints. According to Driver (1994) and Chen et al. (2013), many difficulties physics educators and students face in electronics are due to alternative frameworks which they hold about the topic. Some decades ago, Hunt and Minstrell (1977) highlighted the same thing by stating that learners' difficulties in science occur because students' conceptions before teaching are not taken into account, and therefore communication barriers between instructors and learners cannot be overcome.

The ideas are logical, sensible, and valuable from the students' point of view, strongly held by the students, but may be significantly different from accepted scientific viewpoints and may not be in conformity with the true or the scientific explanation (Osborne, 1983). This is why many physics educators have at one time or the other experienced the frustration of explaining a concept, in what they thought was the clearest possible way, only to be faced with expressions of mute incomprehension from the class (Tytler, 2002). Others have had the experience of having successful conversations in class, in which they felt sure they had achieved some clear understandings, only to find on testing that nothing much seemed to have been gained at all (Tytler, 2002).

Sewell (2002) added that quite often, students with alternative frameworks reject what they are taught and so find it difficult to learn. The same view was shared by Kyle and Shymansky (1989) who supported the idea that alternative frameworks interfere with learning because students resist change. These experiences and feelings seem to contradict what students read in their textbooks and/or are taught by their teachers (Driver et al., 1994). Later, those who undergo a physics teacher training course but still hold on to alternative frameworks about fundamental physics concepts cannot teach physics effectively (Yip et al., 1998). There are several studies that reveal alternative frameworks in basic electronics (Millar, 2012; Driver, 1994; Chen et al., 2013; Lee & Law, 2001; Engelhardt & Beichner, 2004; Sencar & Eryilmaz, 2004; Periago & Bohigas, 2005; Küçüközer & Kocakülah, 2007).

In New York, Millar (2012) did a study in electronics to find out what students thought the nature of cathode rays was. The findings showed that students had mixed feelings about cathode rays. Some thought that cathode rays were particles, others thought they were waves, while still others believed that they were both particles and waves. One can see clearly that generally, students' ideas of cathode rays were not in line with those of physics educators. In other words, they had alternative frameworks about the nature of cathode rays.

Driver (1994) did a study on the behaviour of a resistor in a circuit; the results revealed a preconceived notion held by students that if there was a resistor before a lamp, the resistor would dim the lamp in a circuit, but if the resistor was after the lamp then it would have no effect on the intensity of the light. This showed that the students did not have the understanding that current in a circuit is a flow of charge which is conserved.

Chen et al. (2013) also embarked on a study titled: "Correcting Misconceptions on Electronics: Effects of a simulation-based learning environment backed by a conceptual change model." The concepts of the diode investigated in this study comprised conceptual contents such as "semiconductor concept of a diode," "feature of diode bias," "simplified model of a diode," and "basic circuit of a diode." Researchers investigated the misconceptions about diodes and related concepts by reviewing the literature and conducting a diagnostic test (Lee & Law, 2001; Engelhardt & Beichner, 2004; Sencar & Eryilmaz, 2004; Periago & Bohigas, 2005; Küçüközer & Kocakülah, 2007). Forty questions in the diagnostic test provided by researchers and two subject-matter experts were used to collect information on misconceptions about diodes. First of all, 64 sophomores (who had previously studied diodes) were asked to answer some questions. Their answers were then analysed to summarise all possible misconceptions held by the students. Results indicated that there were 7 misconceptions about "semiconductor concept of a diode," 4 misconceptions about "feature of diode bias," 7 misconceptions about "simplified model of a diode," and 10 misconceptions about "basic circuit of a diode" (Chen et al., 2013).

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Twenty-one of the 28 misconceptions about the concepts of a diode listed were related to semiconductor characteristics, bias types, elementary models, and applicable circuits. Four of them were attributed to incorrect analyses of basic electric current, voltage, and circuit behaviour (i.e., "The output current passing through an element in a circuit is less than the input current," "Incorrect definition of the average output voltage of a rectifier," "Incorrect definition of the RMS (root mean square) output voltage of a rectifier," and "Confusion about concepts of basic series-parallel circuits"), while the last three were ascribed to the interaction between fundamental concepts of current (or voltage) and diode (i.e., "No current in parallel resistances when a diode is conducting," "The current passing through a zener diode is equal to the current passing through a load resistance," and "No current passes through a load resistance when the breakdown voltage is applied to a zener diode") (Chen et al., 2013). These past misconceptions directly affected not only the learning of relevant concepts but also resulted in further misconceptions due to interactions (Chen et al., 2013).

Therefore, it is clear from the aforementioned that pre-service teachers of physics have alternative frameworks which have a negative effect on their performance in basic electronics. While this is so, research does not specify the degree of relationship between student alternative frameworks and their performance in any physics topic in Zambia. Hence, this study sought to determine the correlation between physics pre-service teachers' alternative frameworks and their performance in basic electronics in the Zambian context. The question to be answered was: "What is the correlation between alternative conceptions and performance of pre-service teachers of physics in basic electronics content?" Knowledge of this correlation is crucial if we are to make informed decisions about who and how to handle electronics which has been so challenging to teachers and learners.

Theoretical Framework

The study was informed by the theory of Conceptual Change by Posner, Strike, Hewson, and Gertzog (1982), which originated from the theory of Constructivism by Piaget (1962). Two key terms in Piaget's work were Assimilation and Accommodation. The former denotes the fitting of new experiences into existing mental schemes while the latter, a related term, describes the changing of mental schemes that are unable to explain one's new experiences (Von Glasersfeld, 1995). Building on these fundamental concepts, Posner et al. (1982, p. 211) articulated a theory that explains and describes the "substantive dimensions of the process by which people's central, organising concepts change from one set of concepts to another set, incompatible with the first," a "conceptual change" learning model (CCM). The central commitment of the conceptual change learning model is that learning is a rational activity that can be defined as coming to comprehend and accept ideas because they are seen as intelligible and rational; the "aha" experience is of utmost importance in learning (Hewson, 1992).

There are two major components to the CCM. The first of these components is the conditions that need to be met (or no longer met) in order for a person to experience conceptual change. The second component is the person's conceptual ecology that provides the context in which the conceptual change occurs, that influences the change, and gives it meaning. The conceptual ecology consists of many different kinds of knowledge, the most important of which may be epistemological commitments (e.g., consistency or generalisability), metaphysical beliefs about the world (e.g., the nature of time), and analogies and metaphors that might serve to structure new information. Learners use their existing knowledge (i.e., their conceptual ecology) to determine whether different conditions are met, that is whether a new conception is intelligible (knowing what it means), plausible (believing it to be true), and fruitful (finding it useful). If the new conception is all three, learning proceeds without difficulty (Hewson, 1992).

Learning a new conception means that its status rises, that is, the learner understands it, accepts it, and sees that it is useful. If the new conception conflicts with an existing conception, that is, one that already has high status for the learner, it cannot be accepted until the status of the existing conception is lowered. This only happens, according to the CCM, if the learner holding the conception has reason to be dissatisfied with it (Posner et al., 1982).

The implication of the theory is that if the learner does not accept what is being taught as intelligible and rational due to alternative frameworks one holds about any concept, learning of that concept will be difficult and in turn performance will be low. This points to a negative relationship between alternative frameworks and performance

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of learners, that is, the more alternative frameworks one has on a topic the lower will be one's performance on that topic and vice versa.

LITERATURE REVIEW

It is clear from so much research in physics education that student teachers of physics do not enter the classroom as "empty vessels" but are filled with various conceptions about fundamental physics concepts which they are going to learn (Tytler, 2002; Knight, 2002). Some of their conceptions are in conformity with scientific explanation while others differ from accepted scientific viewpoints and so are commonly known as alternative conceptions, alternative frameworks or misconceptions (Driver & Easley, 1978; Driver, 1983; Driver & Erickson, 1983; Blosser, 1987; Boyes, 1988; Treagust, 1988; Veiga, 1989; Rowell, Dawson & Lyndon, 1990; McDermott, 1993; Wandersee, Mintzes & Novak, 1994; Coetzee, 1998; Yip et al., 1998; Groves & Pugh, 1999; Palmer, 1999; Knight, 2002; Papadimitriou, 2004). Examples of alternative conceptions are that:

- Motion of an object implies a force acting on the object.
- Electric current gets used up as it flows through a circuit (Knight, 2002, p. 27).

So far no research has been done in Zambia to ascertain the conceptions explained earlier. However, the researchers' teaching experience at secondary, college and university levels, including their monitoring of school teaching experience (STP) and peer teaching sessions, pointed to the fact that student teachers of physics in this country also held similar views. For example, during physics education classes in Zambia, some student teachers of physics claimed that when a body is falling freely under gravity, the rate at which its velocity changes increases as the object approaches the earth. Some of them did not accept the fact that if a body is already in motion and there is no opposing force, we do not need an external force to keep it in motion. Others did not easily accept that a lens maintains its refractive properties regardless of its size. There were learners who seemed to know that electric current is a flow of charge, but they did not appreciate that charge is a conserved quantity and so, it does not finish. All these alternative conceptions are similar to the ones already revealed by research, which are held by student teachers of physics in other countries. No wonder Tytler (2002) contended that, "Students from different countries and cultures have been found to have very similar prior ideas, so that there seems to be a common set of alternative conceptions that untutored life experience encourages" (p. 3).

Causes of Alternative Frameworks

Research in physics education indicates that student teachers' alternative frameworks may arise as a result of several reasons, such as: interference of learnt materials, uncritical acceptance of incorrect information, inadequate pre-requisite knowledge, past teaching, a wrong deduction due to fallacious reasoning, the variety of contacts students make with the physical and social world, subjective experience before learning the scientific views, physics textbooks, interaction with people and through the media (Ausubel, 1968; Ivowi, 1984; Clement, 1989; Yip et al., 1998; Ozmen, 2004; Sweetland, 2012). In Zambia, all these sources were contributing to alternative frameworks in physics pre-service teachers but the major ones could be: inadequate pre-requisite knowledge, past teaching and interference of learnt materials. This is because during physics education classes, student teachers explained some fundamental basic electronics concepts in ways which were not in conformity with scientific explanation. When asked why they did so, some claimed that they had inadequate knowledge on the concepts, the majority attributed their answers to what they learnt from teachers of physics at secondary school while the rest admitted that they were confused by similar and abstract concepts which they covered before their tertiary education.

Stability and Resistance to Change

One question worthy asking is whether physics student teachers' alternative conceptions can be minimised, dislodged or changed into scientifically acceptable conceptions. While this is not impossible, it is not an easy thing to do. According to Fisher (1985), once developed, alternative conceptions tend to be highly stable and very resistant to change. Rather than being momentary conjectures that can quickly be discarded, misconceptions

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consistently appear not only before but also after instruction, in substantial numbers of student teachers of physics and are actively defended (Cohen et al., 1983). Smith et al. (1993) report, "Perhaps most troubling is that students can doggedly hold onto mistaken ideas even after receiving instruction designed to dislodge them" (p. 13). As long as a misconception seems to work, it will persist (Semanek, 2008). Summarising years of research into misconceptions in Newtonian mechanics, Clement (1989) also admitted that many misconceptions are deep seated, resistant to change and a serious problem to learners.

Effect of Alternative Frameworks on Learning

Due to their strength and flawed content, alternative frameworks interfere with students' learning of correct scientific principles or concepts (Posner et al., 1982; Fisher, 1985; Knight, 2002; Smith et al., 1993). For example they are the source of students' difficulty in learning "formal" notions of probabilistic events, such as the "Law of small numbers" (Shaughnessy, 1985; Lindquist, 1989). This is supported by Cohen et al. (1983) who argued that misconceptions about circuits "impede" the rigorous study of electricity. Indeed there is enough evidence to suggest that many of the difficulties students encounter in physics content are due to the misconceptions they hold about the subject (Knight, 2002). Hunt and Minstrell (1977) supported this assertion by stating that learners' difficulties in science occur because students' conceptions before teaching are not taken into account and therefore communication barriers between instructors and learners cannot be overcome. The ideas are logical, sensible, and valuable from the students' point of view, strongly held by the students, but may be significantly different from accepted scientific viewpoints and may not be in conformity with the true or the scientific explanation (Osborne, 1983).

In addition, alternative frameworks affect the teaching of physics negatively (Knight, 2002). According to Tytler (2002), "Students' alternative conceptions have proved surprisingly difficult to shift, and can offer a serious barrier to effective teaching" (p. 3). This is why Groves and Pugh (1999) expressed concern about the ability of teachers with alternative frameworks to instruct their students correctly since they, themselves, did not have proper understanding of how the world works. Both theory and common sense support the argument that teachers' inadequacy in subject content knowledge will affect teaching performance as well as pupils' learning (Ball & McDiarmid, 1989; Haambokoma et al., 2002). The complexity and multiplicity of a lesson event, such as selecting suitable content, planning and conducting productive learning activities, asking meaningful questions, answering unprepared questions, diagnosing learning difficulties, and assessing students' progress demand teachers to have a good command of subject knowledge (Yip et al., 1998).

Therefore, it is well established from the aforementioned that student teachers of physics do not come to the classroom with empty minds, but with a wide range of some already strongly held ideas, which in many cases differ from the theories the educator must develop (Driver, 1983). Such ideas are resistant to change and if not taken into account, they make it difficult for student teachers to learn and later teach physics (Cohen et al., 1983; Yip et al., 1998). While this is so, little is known about the degree of relationship that exists between alternative frameworks and performance of pre-service teachers of physics in basic electronics in the Zambian context. Knowing the correlation is very important because based on this knowledge, we can make informed decisions on which steps to take in order to ensure learner conceptual understanding of electronics concepts.

METHODOLOGY

Research Design

The study employed a quantitative approach using a correlation design and a one-case pre-test post-test control group design. The correlation design was used to determine the degree of relationship between alternative frameworks and performance in basic electronics. The one-case pre-test post-test control group design was employed because the same participants were taking part in another study which used a pure experimental design and so required two homogeneous groups, each with 30 participants.

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Study Site and Population

The study was conducted at a higher learning institution in Lusaka District, Zambia. The population comprised all final year pre-service teachers of science (191 BSc. Ed and BEDMAS) in that institution. The choice of a single institution was necessitated by resource constraints and the need for in-depth analysis within a manageable scope. However, this limits the generalisability of the findings, a limitation acknowledged in Section 3.10.

Sample and Sampling

The sample consisted of 60 participants selected using simple random sampling. Thirty of them constituted the experimental group while the rest formed the control group after randomisation. The reason for this is that although this study used one group with all the 60, the same participants were taking part in another study which used a pure experimental design and so required two homogeneous groups, each with 30 participants.

Instruments

Two instruments were used for data collection:

1. Structured Questionnaire on Alternative Frameworks in Basic Electronics

The questionnaire was designed to identify alternative frameworks held by participants in basic electronics. It consisted of 25 items covering key concepts in basic electronics, including:

- Electric current and charge conservation (5 items)
- Voltage and potential difference (5 items)
- Resistance and Ohm's law (5 items)
- Series and parallel circuits (5 items)
- Semiconductor and diode concepts (5 items)

Each item presented a statement or scenario, and participants were required to indicate their level of agreement or select the correct option from multiple choices. Items were designed to elicit common misconceptions identified in the literature (Driver, 1994; Chen et al., 2013; Engelhardt & Beichner, 2004; Küçüközer & Kocakülah, 2007).

2. Performance Test on Basic Electronics Content

The performance test consisted of 30 multiple-choice questions covering the same five content areas. The test was designed to measure participants' conceptual understanding and problem-solving abilities in basic electronics. The test items were adapted from standard physics education resources and validated by two subject-matter experts.

Validity and Reliability

Validity: Content validity was established through a review by two subject-matter experts in physics education. The experts evaluated the instruments for relevance, clarity, and comprehensiveness, and their feedback was incorporated into the final versions. Construct validity was assessed through factor analysis (see Section 3.5.1 below).

Reliability: A test-retest method was used to check reliability. The instruments were administered to a pilot group of 20 pre-service teachers who were not part of the main sample, with a two-week interval between administrations. The Pearson's correlation coefficient was used because it was the most stable measure.

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Furthermore, the relationship between the variables to be correlated was linear and the sets of data to be correlated represented interval scales.

Reliability coefficients obtained during the study were as follows:

- Structured questionnaire (alternative frameworks): $\alpha = 0.82$
- Performance test: $\alpha = 0.79$
- Test-retest reliability (questionnaire): $r = 0.85$
- Test-retest reliability (performance test): $r = 0.81$

Construct Validity Assessment

To provide evidence of construct validity, an exploratory factor analysis was conducted on the structured questionnaire data from the pilot study. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.78, and Bartlett's test of sphericity was significant ($\chi^2 = 412.6$, $df = 300$, $p < 0.001$), indicating that the data were suitable for factor analysis. The analysis extracted five factors corresponding to the five content areas (electric current, voltage, resistance, circuits, and semiconductors), explaining 68.4% of the total variance. Factor loadings ranged from 0.52 to 0.81, providing evidence of construct validity.

Data Collection Procedure

Two pairs of scores were obtained for each of the respondents in the group. These were the number of alternative frameworks (X) held by a respondent as revealed by the structured questionnaire and the score obtained in electronics content (Y) before and after giving them lectures in basic electronics. The data obtained were used to complete Table 1.

Table 1: Scores Obtained by Participants in Pre- and Post-Tests

Respondent	Number of Misconceptions (X)	Score Obtained in Basic Electronics Content Test (Y)
P1		
P2		
P3		
...		
P59		
P60		
Total = 60		

N = 60

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Note: The letter 'P' represents a participant in the group, while N represents the total number of participants.

Data Analysis

After data collection, the Statistical Package for Social Sciences (SPSS) was used to determine the Pearson's Product Moment Correlation Coefficient, r. The resulting Pearson's 'r' indicated the degree of relationship (correlation) between alternative frameworks and performance of physics student teachers in basic electronics content. Data were analysed using descriptive statistics (Pearson's Product Moment Correlation coefficients) and inferential statistics (t-values).

Ethical Considerations

Ethical clearance all possible methods of protecting the respondents were applied. Participants were informed of the purpose of the study, their right to withdraw at any time, and the confidentiality of their responses. No identifying information was collected. Participants were assigned codes (P1 to P60) to ensure anonymity.

Limitations and Delimitations

Delimitations: The study was delimited to 3rd and 4th year pre-service teachers of physics at a higher learning institution in Lusaka District, Zambia. Though there were many students of physics at 1st and 2nd years who had done basic electronics and some of whom had a teaching experience (in-service teachers), the study was restricted to 3rd and 4th year students to avoid clashes in the timetable.

Limitations: The study acknowledges several limitations. First, only 60 student teachers of physics were used because that was the maximum number the researchers could get, following the sampling method that was used. The relatively small sample size limits the statistical power of the findings and their generalisability to other institutions or contexts. Second, access to respondents was limited to the time when they did their peer teaching. Third, the study employed a correlational design, which does not permit causal inferences to be drawn. While the theoretical framework (Conceptual Change Theory) suggests that alternative frameworks cause poor performance, the correlational findings alone cannot establish causation. Fourth, the study relied exclusively on quantitative data, which cannot explain why particular alternative frameworks persist among pre-service teachers. Qualitative data (e.g., interviews or think-aloud protocols) would have provided richer insights into the cognitive processes underlying conceptual difficulties. Fifth, the study did not investigate other factors that may influence performance, such as prior academic achievement, self-efficacy, instructional quality, or learner motivation. Sixth, the single-institution focus means the findings may not be representative of other teacher education institutions in Zambia or beyond.

Efforts to Mitigate Limitations

To mitigate the limitations described above, several strategies were employed:

1. **Correlational design limitations:** While the study does not claim causation, the theoretical framework (Conceptual Change Theory) provides a basis for understanding the plausible direction of influence. The study recommends future experimental and longitudinal research to establish causal relationships.
2. **Single-institution limitation:** The study provides detailed contextual information to enable readers to assess transferability. The recommendations call for replication studies at multiple institutions.
3. **Lack of qualitative data:** The study acknowledges this limitation and suggests that future research incorporate qualitative methods such as interviews or think-aloud protocols.

FINDINGS AND DISCUSSION

The research question to be answered was: "What is the correlation between student teachers' alternative frameworks and their performance in basic electronics content?"

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Correlation of Scores with Alternative Frameworks in the Pre-Test

The findings in the pre-test for experimental and control groups combined are presented in Figure 1.

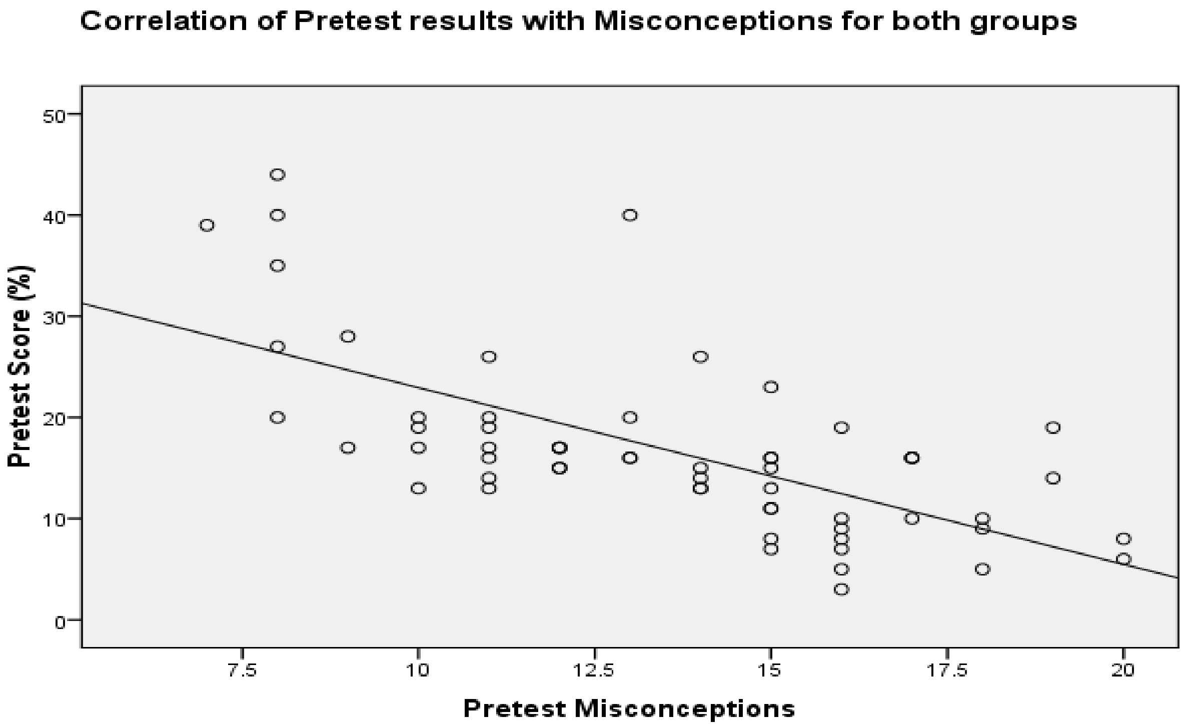

Figure 1: Correlation of Scores with Alternative Frameworks in the Pre-Test

Figure 1 shows a linear graph with a negative gradient, suggesting that the relationship between the scores obtained in the pre-test and participant alternative frameworks was negative. This indicates that as participant alternative conceptions increased, their performance in basic electronics got lower and vice versa. Therefore, the graph shows the relationship between the two variables in question but does not provide the degree of relationship.

Pearson's Product Moment Correlation for the Whole Group Before the Treatment

Pearson's Product Moment Correlation coefficient before the treatment was as shown in Table 2.

Table 2: Pearson's Product Moment Correlation Before the Treatment

		Pretest Score	Misconceptions
Pretest Score	Pearson Correlation	1	-0.7**
	Sig. (2-tailed)		0.0
	Sum of Squares and Cross-products	4589.6	-1150.8
	Covariance	77.8	-19.5

		Pretest Score	Misconceptions
	N	60	60
Misconceptions	Pearson Correlation	-0.7**	1
	Sig. (2-tailed)	0.0	
	Sum of Squares and Cross-products	-1150.8	659.0
	Covariance	-19.5	11.2
	N	60	60

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

The Pearson's Product Moment Correlation for the whole group was **-0.7** (sig at 0.00, 2-tailed) at 99% confidence interval, to one decimal place. This indicated that as the number of alternative frameworks held by pre-service teachers increased, their performance became lower and vice versa. The coefficient of determination (r^2) was 0.49, indicating that **49% of the variance in performance could be explained by alternative frameworks**. This is a substantial effect size. These findings were consistent with both the theoretical framework and literature reviewed which supported the fact that alternative frameworks had a negative effect on performance of learners (Posner et al., 1982; Fisher, 1985; Knight, 2002; Smith et al., 1993).

Correlation of Scores with Alternative Frameworks in the Post-Test

Figure 2 shows the graph of scores obtained by the experimental and control groups combined versus their alternative conceptions after the treatment.

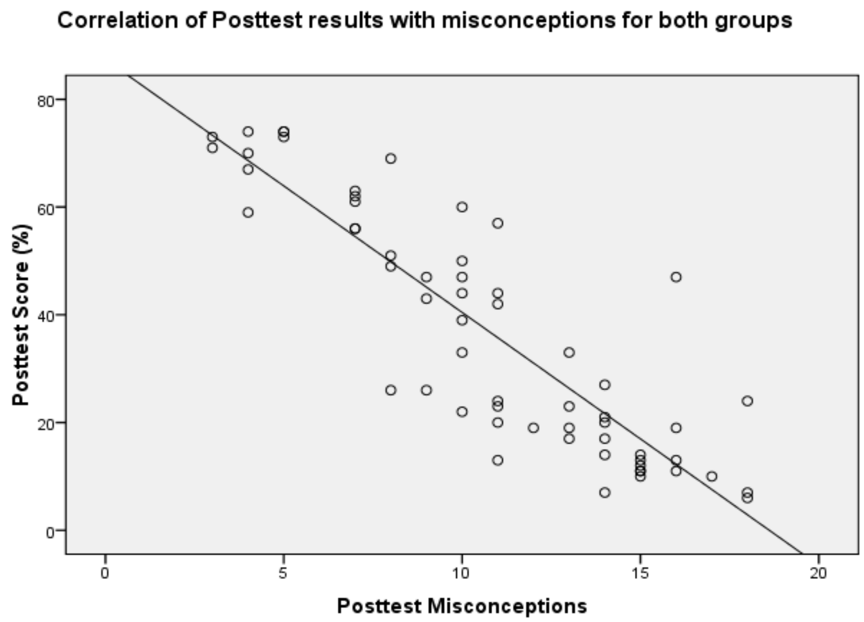

Figure 2: Correlation of Scores with Alternative Frameworks in the Post-Test

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Again, the gradient of the graph was negative, showing a negative correlation between the variables involved. This was in line with both the theoretical framework and the literature reviewed except that it does not provide the degree of relationship between the variables in question (Shaughnessy, 1985; Lindquist, 1989). Using SPSS, the correlation coefficient was computed as shown in Table 3.

Pearson's Product Moment Correlation for the Group After the Treatment

Pearson's Product Moment Correlation coefficient after the treatment for the whole group was as shown in Table 3.

Table 3: Correlations After Treatment

		Misconceptions	Post Scores
Misconceptions	Pearson Correlation	1	-0.9**
	Sig. (2-tailed)		0.0
	Sum of Squares and Cross-products	1015.7	-4770.0
	Covariance	17.2	-80.8
	N	60	60
Post Scores	Pearson Correlation	-0.9**	1
	Sig. (2-tailed)	0.0	
	Sum of Squares and Cross-products	-4770.0	29426.9
	Covariance	-80.8	498.8
	N	60	60

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

The value of Pearson's Product Moment Correlation for the group after the treatment was **-0.9** (sig at 0.00, 2-tailed) at 99% confidence interval. This showed that as number of alternative frameworks dropped, participant performance in basic electronics increased. The coefficient of determination (r^2) was 0.81, indicating that **81% of the variance in performance could be explained by alternative frameworks** after the treatment.

DISCUSSION OF FINDINGS

The findings revealed a strong negative correlation between alternative frameworks and performance both before and after the treatment. The correlation coefficient of -0.7 before the treatment indicates that 49% of the variance in performance could be explained by alternative frameworks. This is a substantial effect size. After the treatment, the correlation coefficient increased to -0.9, indicating that 81% of the variance in performance could be explained by alternative frameworks. This increase is noteworthy and suggests that addressing alternative frameworks had a significant impact on performance.

The implication is that alternative frameworks are not merely minor obstacles but are significant predictors of performance in basic electronics. The stronger correlation after the treatment suggests that once learners engage with the content more deeply (as they did after the lectures), their alternative frameworks become more salient in determining their performance. This aligns with the conceptual change theory which posits that learners' existing conceptions play a crucial role in how they process and retain new information (Posner et al., 1982).

Explanations for the difference in correlation coefficients before and after the treatment:

Several possible explanations for the increase in correlation strength from -0.7 to -0.9 after the treatment are worth considering:

1. **Instructional quality:** The lectures delivered between the pre-test and post-test may have been of sufficient quality to engage participants deeply with the content, making their existing alternative frameworks more salient. When learners are actively processing new information, their prior conceptions are activated and become more influential in shaping learning outcomes (Posner et al., 1982).

2. **Differential learning gains:** Participants who had fewer alternative frameworks before the instruction may have been better positioned to benefit from the lectures, leading to greater learning gains. Conversely, those with more alternative frameworks may have experienced greater difficulty in learning the new material, widening the performance gap between the two groups.

3. **Learner motivation and engagement:** Participants with fewer alternative frameworks may have been more confident and motivated to engage with the content, while those with more alternative frameworks may have experienced frustration or disengagement, further affecting their performance.

4. **Interaction effects:** The interaction between alternative frameworks and other variables such as prior academic achievement, self-efficacy, and learning strategies may have become more pronounced after the treatment, leading to a stronger observed correlation.

5. **Methodological considerations:** The post-test may have been more sensitive to the specific alternative frameworks identified in the questionnaire, leading to a stronger correlation. Alternatively, the reduction in the number of alternative frameworks after instruction may have increased the relative influence of remaining alternative frameworks on performance.

Alternative explanations for the observed findings:

While the theoretical framework supports the interpretation that alternative frameworks cause poor performance, alternative explanations should be considered:

1. **Prior academic ability:** Students with stronger prior academic ability may have both fewer alternative frameworks and better performance, making the correlation a reflection of general academic ability rather than a specific effect of alternative frameworks.

2. **Instructional quality:** The lectures provided between the pre-test and post-test may have been more effective for some participants than others, influencing both the reduction in alternative frameworks and the improvement in performance.

3. **Motivation and engagement:** Students who are more motivated and engaged may be more likely to revise their alternative frameworks and perform better on assessments.

4. **Measurement artefacts:** The observed correlation may be influenced by shared method variance, as both the alternative frameworks questionnaire and the performance test were self-report measures.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

The study acknowledges these alternative explanations and recommends future research to investigate them more systematically.

Consistency with Previous Research

The findings are consistent with international research demonstrating the negative impact of alternative frameworks on performance in physics. For example, Chen et al. (2013) found that addressing misconceptions through simulation-based learning environments led to improved conceptual understanding. Similarly, Engelhardt and Beichner (2004) reported that students' understanding of direct current resistive electrical circuits was significantly affected by their prior conceptions. Sencar and Eryilmaz (2004) found that Turkish secondary school students held numerous misconceptions about simple electric circuits, which affected their performance.

The study extends this international literature to the Zambian context, providing empirical evidence that the relationship between alternative frameworks and performance observed in other countries also holds true in Zambia. This supports Tytler's (2002) observation that students from different countries and cultures have very similar prior ideas.

Implications for Physics Teacher Education

The findings have significant implications for physics teacher education in Zambia:

1. **Diagnostic assessment:** Physics educators should use diagnostic assessments to identify pre-service teachers' alternative frameworks before instruction, enabling them to address these conceptions directly.

2. **Conceptual change strategies:** Teacher education programmes should incorporate conceptual change strategies, such as cognitive conflict, analogical reasoning, and simulation-based learning, to help pre-service teachers revise their alternative frameworks.

3. **Curriculum design:** The physics curriculum at both secondary and tertiary levels should include explicit attention to common alternative frameworks in electronics, with instructional strategies designed to address them.

4. **Professional development:** Physics educators should receive professional development on identifying and addressing alternative frameworks in their teaching practice.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The study concluded that there was a strong negative correlation between physics pre-service teachers' alternative frameworks and their performance in basic electronics before and after the treatment ($r = -0.7$ and -0.9, sig at 0.00, 2-tailed) at 99% confidence level of interval. This correlation was consistent across both pre-test and post-test, confirming that alternative frameworks are a significant predictor of performance in basic electronics.

The study further concluded that the stronger correlation after the treatment ($r = -0.9$) suggests that as learners engage with the content more deeply, their alternative frameworks become more influential in determining their performance. This has significant implications for physics teacher education programmes.

While the correlational design does not permit causal inferences, the findings are consistent with the theoretical framework (Conceptual Change Theory) and the substantial body of international literature suggesting that alternative frameworks cause poor performance. However, alternative explanations such as prior academic ability, instructional quality, and learner motivation should be investigated in future research.

Recommendations

Based on the findings, the following recommendations are made:

1. **Physics educators** in the higher learning institution in question should pay attention to alternative frameworks and clarify them so that pre-service teachers could have a conceptual understanding of basic electronics before they get into the teaching profession to handle learners.

2. **Teacher education programmes** should incorporate strategies for identifying and addressing alternative frameworks in physics content, particularly in challenging areas such as electronics.

3. **Curriculum developers** should consider integrating conceptual change strategies into the physics curriculum at both secondary and tertiary levels.

4. **Further research** should be conducted to identify the specific alternative frameworks held by physics pre-service teachers in Zambia and to develop context-specific interventions for addressing them.

5. **Future studies** should expand the investigation to multiple universities and teacher education institutions across Zambia to improve external validity and determine whether the observed relationship between alternative frameworks and performance is consistent across different educational settings.

6. **Future research** should employ qualitative methods, such as interviews or think-aloud protocols, to explore why specific alternative frameworks persist despite formal instruction.

7. **Longitudinal or experimental designs** should be used to examine causal relationships between conceptual change interventions and improvements in academic performance.

8. **Additional variables** such as prior academic achievement, self-efficacy, instructional approaches, and learning strategies should be investigated to provide a more comprehensive understanding of factors influencing conceptual understanding in electronics.

Contributions to Knowledge

This study makes a significant contribution to the literature by:

1. Providing empirical evidence on the correlation between alternative frameworks and performance in basic electronics in the Zambian context.

2. Demonstrating that alternative frameworks are strong predictors of performance in basic electronics (accounting for 49-81% of the variance in performance).

3. Extending the application of conceptual change theory to the Zambian physics education context.

4. Providing baseline data for future research on alternative frameworks in physics in Zambia.

Limitations and Suggestions for Future Research

The study acknowledges the following limitations:

1. The study was conducted at a single higher learning institution with a relatively small sample of 60 participants, which limits the generalisability of the findings.

2. The correlational design does not permit causal inferences.

3. The study relied exclusively on quantitative data and cannot explain why particular alternative frameworks persist.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

4. The study did not investigate other factors that may influence performance, such as prior academic ability, self-efficacy, or instructional quality.

Future research should address these limitations by expanding to multiple institutions, employing qualitative methods, and investigating additional variables.

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