



## Alternative conceptions and students' achievement in basic science and technology: Evidence from upper basic education

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### Abstract

**Background:** In science education, students are expected to develop an understanding of concepts, principles, and scientific reasoning. However, many learners enter the classroom with pre-existing alternative conceptions shaped by their everyday experiences. These prior understandings may not always align with scientific explanations and can influence how students engage with and interpret new knowledge in Basic Science and Technology.

**Aims:** Building on this concern, the present study examined the relationship between alternative conceptions and students' achievement in Basic Science and Technology among Upper Basic Education learners.

**Method:** To address this aim, an ex-post facto descriptive research design was employed. A total of 398 Upper Basic Education 1 students were selected from three educational zones in Benue State, Nigeria. Data were collected using the Basic Science Alternative Conceptions Identification Checklist and the corresponding achievement test. The data were analyzed using frequency counts, percentages, mean, standard deviation, and t-test at a 0.05 level of significance.

**Results:** The analysis indicated that students held alternative conceptions across multiple Basic Science concepts. These conceptions were found to have a significant negative influence on students' achievement. In addition, the findings revealed no significant difference in the influence of alternative conceptions on achievement between male and female students.

**Conclusion:** Overall, the study highlights that alternative conceptions remain prevalent among Upper Basic Education students and play a significant role in shaping their achievement in Basic Science and Technology. Addressing these conceptions through appropriate instructional strategies is therefore essential for improving students' learning outcomes.

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## INTRODUCTION

Science education is widely recognized as a key foundation for developing individuals who are able to understand natural phenomena and respond to real-world challenges in a rapidly changing technological environment (Cho & Park, 2023; Dare et al., 2021). Beyond the acquisition of factual knowledge, science learning is expected to foster conceptual understanding, reasoning ability, and the capacity to apply knowledge in meaningful ways, as emphasized in various educational frameworks (Morris, 2025). Within Basic Science and Technology, these expectations are reflected in the introduction of fundamental concepts that gradually build students' scientific understanding.

In classroom practice, the teaching of Basic Science and Technology is closely linked to students' prior experiences. Learning activities are often designed to connect scientific ideas with

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familiar contexts so that students can relate new knowledge to what they already know (Fries et al., 2021). Through this process, students are expected to construct understanding progressively, moving from simple interpretations toward more structured scientific explanations, a process widely discussed in constructivist learning perspectives (Meli et al., 2022). Despite these intentions, evidence from classroom assessments and examination reports indicates that many students still encounter difficulties when dealing with basic scientific concepts (Al-Mamary, 2022; Mason & Zaccoletti, 2021). Students frequently struggle to explain ideas clearly, differentiate between related concepts, or apply their knowledge in new situations, which reflects deeper issues in conceptual understanding. Such difficulties suggest that the issue is not merely procedural, but is closely related to how students internally organize and interpret scientific knowledge.

A closer look at this issue reveals that students do not enter the classroom as blank slates. Instead, they bring with them a range of prior ideas shaped by everyday experiences and informal learning (Ardoin & Heimlich, 2021). While some of these ideas may support new learning, others may conflict with scientific explanations. These conflicting understandings, often described as alternative conceptions, can influence how students interpret new information and respond to instruction (Potvin, 2023). Alternative conceptions tend to be stable and are not easily replaced through conventional teaching approaches, as noted in studies on conceptual change (Mladenovici et al., 2022). When these conceptions persist, they may limit students' ability to develop accurate scientific understanding and, in turn, affect their academic performance (Fujiyama et al., 2021). For this reason, examining the role of alternative conceptions becomes essential for improving students' achievement in Basic Science and Technology, particularly at the Upper Basic Education level.

Studies in science education consistently highlight the importance of prior knowledge in shaping learning outcomes. Students often develop initial ideas about scientific phenomena before formal instruction, and these ideas may either support or hinder subsequent learning. Alternative conceptions, in particular, have been widely documented across different scientific domains and age groups, suggesting that they are a persistent feature of science learning (Conrad & Libarkin, 2022). The theory of conceptual change explains that meaningful learning occurs when students are able to revise or reorganize their existing mental models (Bryce & Blown, 2024). However, this process is often difficult because alternative conceptions are deeply rooted and resistant to change. As a result, students may continue to rely on incorrect interpretations even after formal instruction has taken place. Empirical findings further indicate that students' academic achievement in science is closely related to their conceptual understanding. When students rely on alternative conceptions, they tend to experience difficulties in tasks that require explanation, reasoning, and application. This highlights the importance of addressing these conceptions in order to improve learning outcomes.

Although research on alternative conceptions has been widely conducted, several important issues remain insufficiently explored (Matsler et al., 2021). Many existing studies focus primarily on identifying the types of alternative conceptions held by students, while fewer studies examine how these conceptions are directly associated with students' academic achievement in measurable terms. Consequently, the strength and nature of this relationship are not always clearly established. In addition, limited empirical evidence specifically addresses this issue within the context of Basic Science and Technology at the Upper Basic Education level (Albadarin et al., 2024; Almasri, 2024). Given that this stage represents a critical foundation for future science learning, the lack of focused investigation in this area constitutes a significant research gap. Furthermore, findings related to gender differences in science learning remain inconsistent (Korlat et al., 2021). Some studies suggest that gender influences academic achievement, while others report no significant differences. This inconsistency indicates the need for further investigation to clarify whether gender moderates the relationship between alternative conceptions and students' achievement (Hsieh & Yu, 2023).

Understanding the influence of alternative conceptions on students' achievement is essential for improving the effectiveness of science teaching and learning (Banda & Nzabahimana, 2023). By identifying the nature and impact of these conceptions, educators can design instructional strategies that facilitate conceptual change and promote deeper understanding. The findings of this study are expected to contribute to more effective classroom practices and curriculum implementation, particularly at the Upper Basic Education level.

This study aims to examine the influence of alternative conceptions on students' achievement in Basic Science and Technology among Upper Basic Education learners. Specifically, it seeks to identify the alternative conceptions held by students, determine the extent to which these conceptions affect their academic achievement, and examine whether the influence of alternative conceptions on achievement differs between male and female students.

## METHOD

### Research Design

This study adopted an ex-post facto descriptive research design to examine the influence of alternative conceptions on students' achievement in Basic Science and Technology. This design was considered appropriate because the independent variable, alternative conceptions, had already occurred and could not be manipulated by the researcher. Instead, the study focused on observing existing conditions and analyzing how these conditions relate to students' achievement.

### Participants

The study was conducted in Benue State, Nigeria, involving Upper Basic Education 1 students enrolled in government-approved secondary schools. The target population consisted of 79,600 students drawn from 732 schools. From this population, a sample of 398 students was determined using Taro Yamane's formula to ensure adequate representation. To obtain the sample, a combination of proportionate stratified sampling, purposive sampling, and simple random sampling techniques was employed. Fourteen schools were selected based on relevant criteria, after which students were randomly chosen to participate in the study. The final sample comprised 198 male and 200 female students, providing a balanced representation for comparative analysis.

### Research Procedure

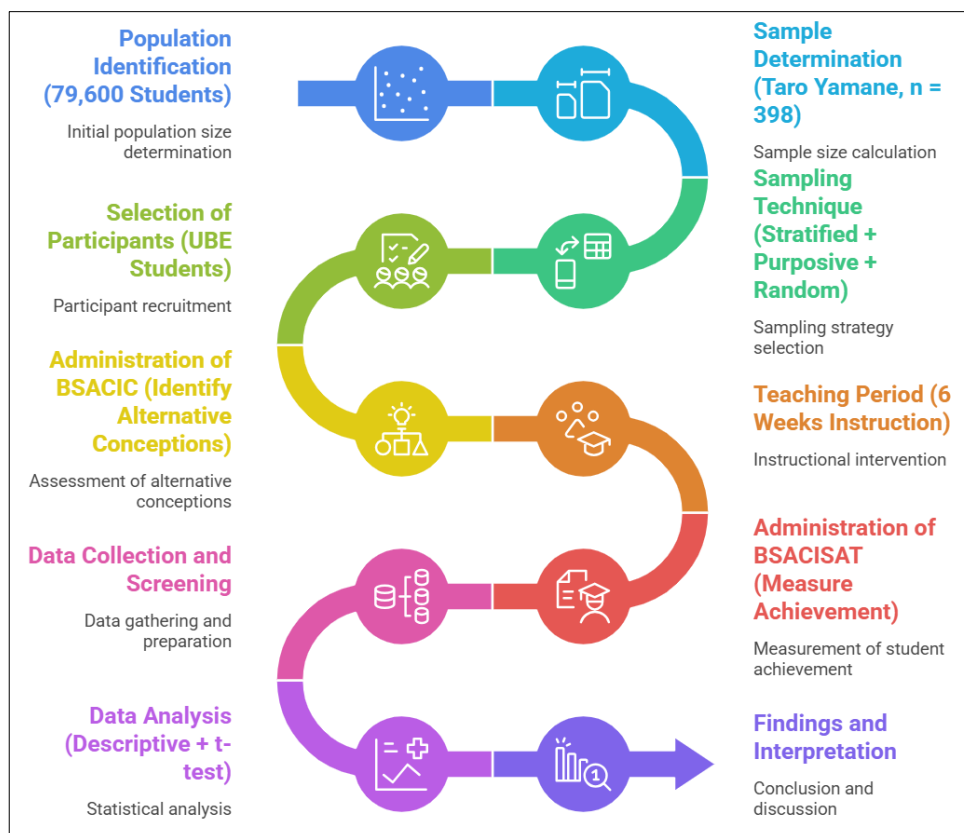
The study was carried out through a sequence of stages designed to ensure systematic data collection. Initially, permission was obtained from the relevant school authorities, and research assistants were briefed to ensure consistency in administering the instruments. This preliminary step was important in preparing the research setting and minimizing procedural bias. Following this preparation, the Basic Science Alternative Conceptions Identification Checklist (BSACIC) was administered to identify students' existing alternative conceptions. This stage provided baseline information regarding students' prior understanding of selected Basic Science concepts. After the initial data collection, students continued with their regular classroom instruction for a period of six weeks. This phase allowed for the natural progression of teaching and learning without intervention, ensuring that the study remained consistent with the ex-post facto design. At the end of the instructional period, the Basic Science Alternative Conceptions Influence on Students' Achievement Test (BSACISAT) was administered to the same group of students to measure their academic achievement. The researcher supervised the entire process, while research assistants supported the administration to ensure that the procedures were carried out uniformly across all participating schools. The overall sequence of the research procedure is illustrated in Figure 1, which presents the flow of activities from population identification to data analysis.

## Instruments

Two instruments were used to collect the required data. The first instrument, the Basic Science Alternative Conceptions Identification Checklist (BSACIC), was designed to identify the alternative conceptions held by students. The second instrument, the Basic Science Alternative Conceptions Influence on Students' Achievement Test (BSACISAT), was used to assess students' achievement in selected Basic Science and Technology concepts. Both instruments underwent face and content validation by three experts in science education and measurement and evaluation. To establish reliability, a pilot test was conducted with 30 students outside the study area. The reliability coefficients were determined using the Kuder–Richardson Formula (KR-20), yielding values of 0.74 for the BSACIC and 0.87 for the BSACISAT, indicating acceptable levels of internal consistency.

## Data Analysis

The collected data were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics, including frequency counts and percentages, were used to identify the presence of alternative conceptions among students. Mean and standard deviation were employed to describe students' achievement levels. To further examine the relationship between variables, inferential analysis was conducted using t-tests. These tests were used to determine the influence of alternative conceptions on students' achievement as well as to examine differences based on gender. All hypotheses were tested at a 0.05 level of significance.



**Figure 1.** Research Procedure of the Study

## RESULTS AND DISCUSSION

### Results

#### *Alternative Conceptions Held by Students*

The distribution of students' responses presented in Table 1 indicates that alternative conceptions were evident across all selected Basic Science concepts. In each concept area, more than

half of the students demonstrated alternative conceptions, with an overall proportion reaching 70.6%.

**Table 1.** Frequency and Percentage Data collected

Concept	Responses		Remarks
	False	True	
Nutrition	157(39.5%)	241(60.5%)	Alternative Conceptions Exist
Excretion	16 (4.0%)	382(96.0%)	Alternative Conceptions Exist
Respiration	118(29.7%)	280(70.3%)	Alternative Conceptions Exist
Reproduction	75(18.8%)	323(81.2%)	Alternative Conceptions Exist
Plants	122(30.7%)	276(69.3%)	Alternative Conceptions Exist
Living things	111(27.9%)	287(72.1%)	Alternative Conceptions Exist
Irritability	119(29.9%)	279(70.1%)	Alternative Conceptions Exist
Matter	166(41.7%)	232(58.3%)	Alternative Conceptions Exist
Animals	182(45.7%)	216(54.3%)	Alternative Conceptions Exist
Mass	96(24.1%)	302(75.9%)	Alternative Conceptions Exist
Metals	122(30.7%)	276(69.3%)	Alternative Conceptions Exist
Evaporation	185(46.5%)	213(53.5%)	Alternative Conceptions Exist
Weight	134(33.7%)	264(66.3%)	Alternative Conceptions Exist
Water	69(17.3%)	329(82.7%)	Alternative Conceptions Exist
Non-living thing	75(18.8%)	323(81.2%)	Alternative Conceptions Exist
<b>Total</b>	<b>117(29.4%)</b>	<b>281 (70.6%)</b>	

This pattern suggests that alternative conceptions are not limited to specific topics but are consistently present across different areas of Basic Science and Technology. The relatively high percentages observed across all items indicate that these conceptions are deeply embedded in students' prior knowledge and continue to influence their understanding during classroom learning.

### Influence of Alternative Conceptions on Students' Achievement

Building on this finding, the results in Table 2 provide further insight into how these conceptions relate to students' academic performance. The mean score for alternative conceptions ( $M = 55.71$ ,  $SD = 11.08$ ) was notably higher than the mean achievement score ( $M = 36.60$ ,  $SD = 10.85$ ), resulting in a mean difference of 19.11.

**Table 2.** The Mean Score and Standard Deviation

	Mean	N	Std. Deviation
Conception	55.71	398	11.08
Achievement	36.60	398	10.85
Mean difference	19.11		

This difference reflects a tendency for students with stronger alternative conceptions to demonstrate lower levels of achievement. The similarity in standard deviation values suggests that this pattern is relatively consistent across the sample, rather than being driven by a small number of extreme cases.

### Hypothesis Testing: Influence of Alternative Conceptions

To examine this relationship more rigorously, a paired sample t-test was conducted, and the results are presented in Table 4. The analysis revealed a statistically significant influence of alternative conceptions on students' achievement ( $t = 23.07$ ,  $df = 397$ ,  $p < 0.05$ ). Moreover, the effect size ( $\eta^2 = 0.57$ ) indicates a strong effect, suggesting that alternative conceptions account for a substantial proportion of the variation in students' achievement.

**Table 4.** Paired Sample t-test of Significance

	Pair difference	T	Df	Sig.(2-tailed)	eta squared
	Mean				
Pair Conception and Interest	19.10	23.07	397	0.00	

This finding reinforces the earlier observation that alternative conceptions play a critical role in shaping students' learning outcomes in Basic Science and Technology.

### Gender Differences in Achievement

In addition to examining the overall relationship, the study also explored whether differences existed between male and female students. As shown in Table 3, male students ( $M = 36.77$ ,  $SD = 11.02$ ) obtained slightly higher mean scores than female students ( $M = 36.45$ ,  $SD = 10.72$ ), with a mean difference of 0.32.

**Table 3.** The Mean Score and Standard Deviation of the Difference Between

	Sex	N	Mean	Std. Deviation
Achievement	Male	193	36.77	11.02
	Female	205	36.45	10.72
Mean difference			0.32	

Although the difference is relatively small, it provides an initial indication of variation in achievement across gender groups. However, the closeness of the mean scores suggests that both groups experienced similar levels of academic performance.

### Hypothesis Testing: Gender Differences

To determine whether this observed difference was statistically meaningful, an independent sample t-test was conducted, as presented in Table 5. The results showed no significant difference in the influence of alternative conceptions on achievement based on gender ( $t = 0.30$ ,  $df = 396$ ,  $p > 0.05$ ).

**Table 5.** Independent Sample t-test of Significance Difference

	T	Df	Sig.(2-tailed)	eta squared
Achievement	0.30	396	0.77	0.0002

The very small effect size ( $\eta^2 = 0.0002$ ) further supports this finding, indicating that gender does not meaningfully influence how alternative conceptions affect students' achievement. Taken together, these results suggest that the impact of alternative conceptions on learning outcomes is consistent across male and female students.

### Discussion

The findings of this study indicate that alternative conceptions are widely present across various Basic Science concepts, suggesting that students' prior understanding plays a central role in shaping their learning (Hartelt et al., 2022). Rather than being isolated misconceptions, these conceptions appear to form a consistent pattern across different topic areas. This pattern reflects the way students construct meaning based on their everyday experiences, which often serve as the foundation for interpreting new scientific information (Ardoin & Heimlich, 2021).

Building on this observation, the persistence of alternative conceptions highlights the challenge of achieving meaningful conceptual change in science learning (Potvin, 2023). These conceptions are not easily replaced through routine instructional practices, as they are often deeply embedded in students' cognitive structures. Consequently, students may retain these ideas even after being exposed to formal teaching, which limits their ability to fully engage with scientifically accurate explanations.

This challenge becomes more evident when considering the relationship between alternative conceptions and students' academic achievement. The findings show that students who hold stronger alternative conceptions tend to demonstrate lower levels of achievement (Han, 2021). This suggests that difficulties in science learning are closely related to the quality of students' conceptual understanding rather than merely their ability to recall information. In this sense, achievement in Basic Science and Technology can be seen as an outcome of how well students are able to reconcile their prior knowledge with scientifically accepted concepts (Dost, 2024).

In relation to existing literature, this finding aligns with studies that emphasize the negative impact of misconceptions on learning outcomes (Asberger et al., 2021). At the same time, it is important to recognize that alternative conceptions are not entirely detrimental. When properly identified and addressed, they can serve as a valuable entry point for instructional intervention. This perspective shifts the focus from simply correcting students' errors to facilitating a process of conceptual reconstruction, where learners gradually refine their understanding through guided learning experiences (Sreelohor et al., 2025).

Regarding gender differences, the results of this study suggest that the influence of alternative conceptions on achievement does not vary significantly between male and female students (Heyder et al., 2021). Although slight differences in mean scores were observed, these differences were not statistically meaningful. This indicates that both groups experience similar challenges in dealing with alternative conceptions, and that conceptual understanding, rather than gender, is the more decisive factor in determining students' achievement.

This finding contributes to the broader discussion on gender in science education, where evidence has remained inconclusive (McDonald & Kanske, 2023). While some studies have reported differences in performance between male and female students, others have found no significant variation. The present study supports the view that learning outcomes are more strongly influenced by cognitive and conceptual factors than by gender differences.

Taken together, these findings underscore the importance of addressing alternative conceptions as part of effective science instruction (Kolil & Achuthan, 2024). Teachers need to move beyond traditional teaching approaches and adopt strategies that actively engage students in reflecting on their prior knowledge. By creating learning environments that encourage questioning, discussion, and conceptual restructuring, it becomes possible to support deeper understanding and improve students' achievement in Basic Science and Technology.

### **Implications**

The findings of this study highlight the importance of addressing students' alternative conceptions as a central component of effective teaching in Basic Science and Technology. The strong influence of these conceptions on students' achievement suggests that learning should not be limited to the delivery of factual knowledge, but should also involve deliberate efforts to uncover and reconstruct students' prior understanding. In this context, teachers are encouraged to adopt instructional approaches that promote conceptual change, such as inquiry-based learning, guided questioning, and reflective discussion, which allow students to actively engage with their own thinking. By creating learning environments that challenge existing misconceptions and support the development of scientifically accurate concepts, educators can enhance both the depth of understanding and overall academic achievement of students.

### **Limitations**

This study has several limitations that should be considered when interpreting the findings. The research was conducted within a specific geographical context, which may limit the extent to which the results can be generalized to other educational settings with different characteristics. In addition, the study relied primarily on quantitative data to examine the relationship between alternative conceptions and students' achievement, which may not fully capture the complexity of students' cognitive processes. As a result, the findings provide a broad overview of patterns and relationships but do not offer detailed insights into how and why alternative conceptions are formed or maintained during the learning process.

### **Suggestions**

Future research is encouraged to build upon these findings by expanding both the scope and methodological approach of the study. Investigations involving a wider range of participants across

different regions or educational levels may provide a more comprehensive understanding of how alternative conceptions influence learning outcomes. In addition, the use of mixed-method designs, incorporating qualitative approaches such as interviews or classroom observations, could offer deeper insights into students' thinking processes and the mechanisms underlying conceptual change. Further studies may also focus on testing the effectiveness of specific instructional strategies aimed at reducing alternative conceptions, thereby providing practical guidance for improving teaching and learning in Basic Science and Technology.

## CONCLUSION

The results of this study confirm that alternative conceptions are a prominent feature of students' learning in Basic Science and Technology and play a decisive role in shaping their academic achievement. Rather than functioning as minor errors, these conceptions represent deeply rooted understandings that influence how students interpret and respond to scientific ideas. As such, students who hold stronger alternative conceptions tend to experience greater difficulty in achieving meaningful learning outcomes, highlighting the central importance of conceptual understanding in science education. In light of these findings, it becomes evident that improving students' achievement requires more than the transmission of content knowledge. Instruction must be directed toward engaging students with their existing ideas and supporting the gradual reconstruction of their understanding. This study also shows that the influence of alternative conceptions operates consistently across gender, suggesting that the challenge lies not in demographic differences but in the nature of students' conceptual frameworks. Taken together, these insights emphasize the need for teaching approaches that prioritize conceptual change as a pathway to deeper understanding and more sustainable learning in Basic Science and Technology.

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## AUTHOR CONTRIBUTIONS STATEMENT

JMY : conceptualized the study, designed the research framework, and was responsible for data collection and initial data analysis.

TJA : contributed to the refinement of the research design, supervised the analytical process, and provided critical revisions to the manuscript.

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