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Effects of Challenge-Based Learning and Place-Based Learning on Polytechnic Computer Engineering Students' Retention in Computer Architecture

Sulaiman Abubakar Zubairu[1], Sadiq Buhari Bello[2]
[1]Ahmadu Bello University
[2]Waziri Umaru Federal Polytechnic
Corresponding Author: Sadiq Buhari Bello, sbbello@wufpbk.edu.ng

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ABSTRACT

This study examined the effects of Challenge-Based Learning (CBL) and Place-Based Learning (PBL) on students' retention of Computer Architecture concepts among Computer Engineering students at Waziri Umaru Federal Polytechnic, Birnin Kebbi, Nigeria. A quasi-experimental pre-test, post-test, and retention-test design was employed. The sample consisted of 41 students, with 20 assigned to the CBL group and 21 to the PBL group. Data were collected using the Computer Architecture Achievement Test (CAAT), a 30-item multiple-choice instrument validated by experts and found reliable through the test–retest method ($r = 0.86$). Mean and standard deviation were used to answer the research questions, while paired-sample and independent-sample t-tests were conducted at the 0.05 significance level. The findings showed that both instructional approaches effectively enhanced students' retention of Computer Architecture concepts. No significant difference was found between the retention scores of students taught using CBL and those taught using PBL ($t(35.72) = 0.15$, $p = .883$). The study concludes that both learner-centered approaches are effective for promoting meaningful learning and long-term retention, and recommends their integration into Computer Engineering instruction.

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INTRODUCTION

Computer Architecture is widely recognized as one of the most challenging courses in Computer Engineering education due to its abstract concepts, technical complexity and the interrelated nature of its components (Al-fedaghi, 2021). Although students may demonstrate understanding during classroom instruction or examinations, many often experience difficulties retaining learned concepts over extended periods. This challenge becomes evident when students are unable to recall previously learned principles or apply them effectively in subsequent courses and practical situations. Poor retention of Computer Architecture concepts may hinder students' academic progression and limit their ability to develop the competencies required in professional computing and engineering practice.

In technical and engineering education, retention is particularly important because many concepts are cumulative in nature (Leijon et al., 2021). Students are expected to build new knowledge upon previously learned principles and procedures. When students fail to retain foundational concepts, they often encounter difficulties in understanding advanced topics, resulting in poor learning outcomes and reduced competence. Research has shown that instructional approaches that promote active participation, collaboration, contextual learning and practical application tend to improve knowledge retention compared to traditional lecture-based methods (Freeman et al., 2014). This is because active learning encourages deeper cognitive processing, which enhances long-term memory and understanding.

Retention is essential in the context of Computer Architecture because students must continuously recall and apply concepts such as instruction execution cycles, processor organization, memory hierarchy, cache systems, input/output operations and hardware-software interactions throughout their academic and professional careers. Effective retention of these concepts enables students to analyse computing systems, troubleshoot hardware-related issues, design efficient computer systems and understand emerging technological innovations. Therefore, instructional strategies capable of improving students' retention of Computer Architecture concepts are necessary for producing competent Computer Engineering graduates.

One factor that may contribute to poor retention is the continued reliance on traditional lecture-based instructional approaches, which often emphasize passive reception of information rather than active engagement and practical application (Al-fedaghi, 2021). Such approaches may promote short-term memorization rather than deep understanding and long-term knowledge retention. In response, educational researchers have advocated for learner-centred pedagogies such as Challenge-Based Learning and Place-Based Learning, which encourage active participation, contextualized learning, collaborative inquiry and experiential engagement (Taconis & Bekker, 2023). These approaches are believed to facilitate deeper learning experiences that can enhance knowledge retention (Huesca et al., 2024).

Despite the growing popularity of Challenge-Based Learning and Place-Based Learning in contemporary education, there is limited empirical evidence regarding their effectiveness in promoting retention of Computer Architecture concepts among Computer Engineering students, particularly within polytechnic institutions. Furthermore, it remains unclear which of the two instructional strategies is more effective in facilitating long-term retention of knowledge. Therefore, there is a need to investigate the effects of Challenge-Based Learning and Place-Based Learning on students' retention in Computer Architecture and to determine the instructional strategy that is more suitable for enhancing long-term learning outcomes among Computer Engineering students of Waziri Umaru Federal Polytechnic Birnin Kebbi.

The findings of this study may provide valuable insights into instructional approaches capable of enhancing students' retention of Computer Architecture concepts. The study may benefit Computer Engineering lecturers by identifying learner-centred strategies that promote deeper understanding and long-term knowledge retention. Such information may assist educators in selecting and implementing instructional approaches that improve students' ability to recall and apply learned concepts beyond immediate classroom assessments. The findings may also be useful to curriculum developers and educational administrators by providing empirical evidence on effective pedagogical practices for technical and engineering education.

LITERATURE REVIEW

Concept of Retention

Retention is a critical outcome of the teaching and learning process and refers to the ability of learners to preserve acquired knowledge, skills and experiences over a period of time and retrieve them when needed (Amin & Malik, 2014). Educational psychologists consider retention an important indicator of meaningful learning because learning is only valuable when acquired knowledge can be remembered and applied in future situations. Unlike short-term memorization, retention involves the long-term storage and recall of information, enabling learners to transfer knowledge to new contexts and solve problems effectively (AERO, 2025). Consequently, retention has become a key consideration in evaluating the effectiveness of instructional strategies across educational disciplines.

Computer Architecture

Computer Architecture refers to the conceptual design, functional organization, and operational structure of computer systems, including processors, memory units, input/output systems, storage devices and communication pathways that enable computers to execute instructions efficiently (Grimes, 2002). The discipline serves as the bridge between hardware and software by explaining how computing systems process, store and manage information. It encompasses critical concepts such as processor design, instruction execution, memory hierarchy, system performance optimization and hardware-software interaction (Ceze et al., 2016). As a core component of Computer Engineering curricula, Computer Architecture provides students with foundational knowledge necessary for understanding computer systems and designing efficient computing solutions.

Challenge Based Learning (CBL)

Challenge Based Learning (CBL) pedagogy was developed by Apple, Inc., to increase motivation and academic achievement among K-12 classrooms. CBL is an active learning and student-centred environment that involves students to plan their learning (Gaskins et al., 2015). CBL looks very similar but it's not Project Base Learning (PBL), even though both approaches provide real-world engagement to problem and involvement in developing solutions (Lara-prieto et al., 2023). Rooted in constructivist learning theory, CBL encourages students to move beyond passive reception of knowledge and actively participate in the learning process through investigation, critical analysis, teamwork and solution development (Bohm et al., 2020) (K. I. Doulougeri et al., 2022). CBL is a learner-centred approach in which students collaboratively address authentic, real-world challenges through hands-on, multidisciplinary projects. It promotes self-directed, reflective and collaborative learning while encouraging students to develop practical solutions or products that have meaningful relevance beyond the classroom (Taconis & Bekker, 2023).

Place-Based Learning (PBL)

Place-Based Learning (PBL) refers to a forms of pedagogy that attempts to connect learning to the immediate local contexts, it's participatory and active in nature. PBL is the process of utilising local and environment context as the first stage of teaching a concept, it emphasises on hands-on and real-life experiences (Elfer, 2011) (Gnyawali et al., 2024). As a student-centred instruction, It is characterised by students' constructive investigations, teamwork, communication and critical thinking within real-world practices (Kokotsaki et al., 2016).

Theoretical Framework

This study was fixed on constructivist learning theory and situated cognition which together provide the theoretical basis for expecting Challenge-Based Learning and Place-Based Learning to enhance the retention of Computer Architecture concepts (Zubairu & Bello, 2026). Constructivist theory ascertain that learners build lasting understanding by actively constructing knowledge through investigation, problem-solving and social interaction rather than through passive receiving information from an instructor (Gatt, 2015; Duffy & Orrill, 2004). Challenge-Based Learning operationalizes this principle requires students to investigate authentic, real-world challenges and generate solutions collaboratively, a process that is theorised to engage deeper and more elaborative cognitive processing than the conventional lecture-based exposure to the same content (K. Doulougeri et al., 2024).

However, Place-Based Learning draws its theoretical grounding from situated cognition and experiential learning theory, which argue that knowledge is more meaningfully encoded and more easily retrieved, when it is learned in relation to a familiar physical, social or environmental setting (Wilson & Myers, 2000). Connecting Computer Architecture concepts to learners' immediate environment and lived experience. Place-Based Learning is theorised to embed new knowledge within a network of appropriate cues that later serve as retrieval aids.

RESEARCH QUESTIONS

1. What is the mean score difference between the post-test and retention-test scores of students taught Computer Architecture using Challenge-Based Learning?
2. What is the mean score difference between the post-test and retention-test scores of students taught Computer Architecture using Place-Based Learning?
3. What is the mean score difference between the retention-test scores of students taught using Challenge-Based Learning and those taught using Place-Based Learning?

HYPOTHESES

HO1: There is no significant difference between the mean post-test and retention-test scores of students taught using Challenge-Based Learning.

HO2: There is no significant difference between the post-test and retention-test scores of students taught using Place-Based Learning.

HO3: There is no significant difference between the retention-test scores of students taught using Challenge-Based Learning and those taught using Place-Based Learning.

METHODOLOGY

This study adopts a quasi-experimental research design. Quasi-experimental design is appropriate where intact groups are used without random assignment of participants to experimental conditions (Sani, 2017). The study involves two instructional groups: (i) Challenge-Based Learning group (Group A) and (ii) Place-Based Learning group (Group B). Both groups were exposed to Computer Architecture instruction using their respective teaching strategies. The population of the study consists of 41 Computer Engineering students enrolled in Waziri Umaru Federal Polytechnic, Birnin Kebbi.

Table 1: Samples for the study

S/N	Group	Samples Selected
1.	Group A: Challenge-Based Learning group	20
2.	Group B: Place-Based Learning group	21
	Total number of students	41

A pre-test was administered to both groups in the first week to determine their baseline knowledge in Computer Architecture. Thereafter, the experimental treatments were conducted over a period of eight (8) weeks. At the end of the treatment period, a post-test was administered to both groups using the same instrument and after three weeks of the post-test a retention test was administered, but with reshuffled items to minimize recall bias and ensure validity of measurement.

Instrumentation

The instrument used for data collection was the Computer Architecture Achievement Test (CAAT), designed to measure students' academic performance in Computer Architecture. The instrument consisted of thirty (30) multiple-choice items with four options (A–D), with only one correct answer per item. The test items were developed based on the course curriculum and validated by subject matter experts to ensure content relevance, clarity and alignment with instructional objectives.

The instrument was further subjected to a pilot study to determine its reliability. The reliability coefficient was established using Pearson's Product Moment Correlation Coefficient (test-retest method), yielding a reliability index of 0.86, which indicates high internal consistency.

Data collected for the study were analysed using both descriptive and inferential statistics. Mean and standard deviation were used to answer the research questions. Paired sample t-test was used to determine the significance of differences between pre-test and post-test scores within each group, while independent sample t-test was used to determine the difference between the post-test scores of the two groups. All hypotheses were tested at 0.05 level of significance.

RESULTS

Table 2: Students Mean Scores of Post-test and Retention-test score in Group-A

S/N	Test	N	Mean Score	Standard Deviation	Mean Difference
1.	Post-test	20	37.25	9.80	1.20
2.	Retention-test	20	36.05	10.30	

Table 2 presents the mean scores of students in Group A before and after the retention interval following exposure to Challenge-Based Learning. The result shows that students obtained a post-test mean score of 37.25 (SD = 9.80) and a retention-test mean score of 36.05 (SD = 10.30), with a mean difference of 1.20. This indicates a slight reduction in performance, suggesting that students retained most of the Computer Architecture concepts learned during instruction.

Table 3: Paired Sample t-Test Analysis of Mean Scores on Post-Test and Retention-Test in Group-A

Test	N	Mean	SD	Mean Difference	95% CI of Difference	t	df	p-value
Post-Test	20	37.25	9.80	1.20	-0.55 – 2.95	1.44	19	0.167
Retention Test (Post-Post Test)	20	36.05	10.29					

Not significant at $p < .05$.

Table 2 presents the paired samples t-test analysis comparing students' post-test and retention test scores. The results show that students obtained a mean score of 37.25 (SD = 9.80) in the post-test and 36.05 (SD = 10.29) in the retention test. The mean difference between the two scores was 1.20. The paired samples t-test revealed that the difference between the post-test and retention test scores was not statistically significant, $t(19) = 1.44$, $p = .167$. This indicates that there was no significant decline in students' performance between the post-test and retention test periods, suggesting that the knowledge gained during challenge-based learning was substantially retained over time.

Table 4: Students Mean Scores of Post-Test and Retention-Test in Group-B

S/N	Test	N	Mean Score	Standard Deviation	Mean Difference
1.	Post-test	21	36.67	6.86	0.19
2.	Retention-test	21	36.48	7.93	

Table 4 presents the mean scores of students in Group B before and after the retention interval following exposure to Place-Based Learning. The findings reveal that students obtained a post-test mean score of 36.67 (SD = 6.86) and a retention-test mean score of 36.48 (SD = 7.93), with a mean difference of 0.19. This indicates a very minimal reduction in performance, suggesting a high level of knowledge retention among students exposed to Place-Based Learning.

Table 5: Paired Sample t-test Analysis of Mean scores on Post-Test and Retention-Test in Group-B

Test	N	Mean	SD	Mean Difference	95% CI of Difference	t	df	p-value
Post-Test	21	36.67	6.86					
Retention Test (Post-Post Test)	21	36.48	7.93	0.19	-1.23 – 1.61	0.28	20	.783

**Not significant at $p < .05$.*

Table 4 presents the paired samples t-test analysis comparing students' post-test and retention test scores. The results indicate that the students obtained a mean score of 36.67 (SD = 6.86) in the post-test and 36.48 (SD = 7.93) in the retention test. The mean difference between the two scores was 0.19. The paired samples t-test revealed that the difference between the post-test and retention test scores was not statistically significant, $t(20) = 0.28$, $p = .783$. This finding indicates that students retained virtually all the knowledge acquired during the instructional period of place-based learning, as there was no significant decline in performance between the post-test and retention test.

Table 6: Mean Difference of Students' Retention-test Scores of Group-A and B

S/N	Test	N	Mean	Standard Deviation	Mean Difference
1.	Retention-Test: Group A	20	36.05	10.30	0.43
2.	Retention-Test: Group B	21	36.48	7.93	

Table 6 shows the retention-test mean scores of students in Groups A and B. The result indicates that students in Group A obtained a mean score of 36.05 (SD = 10.30), while students in Group B obtained a mean score of 36.48 (SD = 7.93), with a mean difference of 0.43 in favour of Group B. This suggests that both instructional strategies produced comparable levels of retention in Computer Architecture among the students.

Table 7: Independent Sample t-test Analysis on Retention-test Mean Scores of Group A and B

Test	Group	N	Mean	SD	Mean Difference	95% CI of Difference	t	df	p-value
Post-Test	Place-Based Learning	21	36.67	6.86	-0.58	-5.98 – 4.81	-0.22	33.87	.827
	Challenge-Based Learning	20	37.25	9.80					
Retention Test	Place-Based Learning	21	36.48	7.93	0.43	-5.42 – 6.27	0.15	35.72	.883
	Challenge-Based Learning	20	36.05	10.29					

**Not significant at p < .05.*

Table 6 presents the independent samples t-test analysis comparing the post-test and retention test scores of students exposed to Place-Based Learning and Challenge-Based Learning. The result revealed no significant difference in the post-test scores of students taught using Place-Based Learning (M = 36.67, SD = 6.86) and those taught using Challenge-Based Learning (M = 37.25, SD = 9.80), $t(33.87) = -0.22$, $p = .827$. Likewise, no significant difference was found in the retention test scores of students taught using Place-Based Learning (M = 36.48, SD = 7.93) and those taught using Challenge-Based Learning (M = 36.05, SD = 10.29), $t(35.72) = 0.15$, $p = .883$. This finding indicates that both instructional strategies were equally effective in promoting retention of Computer Architecture concepts among the students.

DISCUSSION

The findings of this study revealed that there was no significant difference between the post-test and retention-test scores of students exposed to Challenge-Based Learning (CBL). Although the post-test mean score (M = 37.25, SD = 9.80) was slightly higher than the retention-test mean score (M = 36.05, SD = 10.29), the observed difference was not statistically significant, $t(19) = 1.44$, $p = .167$. This finding suggests that students retained most of the Computer Architecture concepts learned through Challenge-Based Learning over the retention period.

The finding is consistent with the principles of Challenge-Based Learning, which emphasize active engagement, authentic problem-solving, collaboration and contextual application of knowledge. Such learning experiences encourage deep cognitive processing and meaningful learning, which are known to enhance long-term retention. The finding supports the systematic review conducted by Doulougeri et al. (2024), which found that Challenge-Based Learning promotes knowledge acquisition, application and sustained engagement in engineering education through authentic real-world challenges. The review concluded that CBL facilitates meaningful learning experiences that extend beyond immediate achievement outcomes.

The finding is also in agreement with Freeman et al. (2014), whose meta-analysis of STEM education studies revealed that active learning approaches significantly improve students' learning outcomes and contribute to stronger retention of learned concepts compared with traditional lecture-based instruction. The authors argued that active engagement enables students to construct durable knowledge structures that enhance long-term memory and recall.

Similarly, Taconis and Bekker (2023) observed that Challenge-Based Learning provides authentic learning environments in which students actively connect theoretical knowledge with real-world challenges. Such authentic experiences encourage deeper understanding and sustained learning, thereby supporting retention of acquired knowledge over time.

The study further revealed that there was no significant difference between the post-test and retention-test scores of students exposed to Place-Based Learning (PBL). Although students recorded a post-test mean score of 36.67 (SD = 6.86) and a retention-test mean score of 36.48 (SD = 7.93), the difference was not statistically significant, $t(20) = 0.28$, $p = .783$. This finding indicates that students retained virtually all the knowledge acquired during instruction through Place-Based Learning. This finding supports the theoretical assumptions of Place-Based Learning, which posit that learning becomes more meaningful when instructional content is connected to learners' local environment, experiences and real-life contexts (Elfer, 2011). Contextualized learning enables students to develop stronger cognitive associations, thereby enhancing long-term retention.

The study also found no significant difference between the retention-test scores of students taught using Challenge-Based Learning and those taught using Place-Based Learning, $t(35.72) = 0.15$, $p = .883$. Although the Place-Based Learning group recorded a slightly higher retention mean score (M = 36.48) than the Challenge-Based Learning group (M = 36.05), the difference was negligible and statistically insignificant. This finding indicates that both instructional strategies were equally effective in promoting retention of Computer Architecture concepts among Computer Engineering students.

This finding corroborates the growing body of literature on learner-centred pedagogies, which suggests that active, contextualized, and experiential learning approaches tend to produce comparable positive effects on students' cognitive outcomes. Freeman et al. (2014) reported that various forms of active learning generally outperform traditional instruction, although differences among active learning approaches themselves are often minimal. Likewise, Doulougeri et al. (2024) noted that Challenge-Based Learning implementations vary considerably across educational contexts, yet consistently support meaningful learning and engagement.

However, the present finding contradicts studies that reported the superiority of one learner-centred strategy over another. Some researchers have found that highly structured problem-solving approaches may produce greater retention gains than contextual learning approaches due to increased cognitive engagement. Conversely, other studies have reported stronger retention outcomes for contextualized learning because of its relevance to learners' lived experiences. The absence of a significant difference in the present study may be attributed to the fact that both Challenge-Based Learning and Place-Based Learning share common pedagogical characteristics, including active participation, collaboration, inquiry, reflection and real-world application, all of which contribute positively to knowledge retention.

Therefore, the findings of this study suggest that both Challenge-Based Learning and Place-Based Learning are effective instructional strategies for promoting long-term retention of Computer Architecture concepts. Their emphasis on authentic learning experiences, student engagement, and meaningful knowledge construction appears to have enabled students to retain acquired knowledge beyond the immediate instructional period.

CONCLUSION

Based on the findings of this study, it can be concluded that both Challenge-Based Learning and Place-Based Learning were effective in promoting students' retention of Computer Architecture concepts among Computer Engineering students of Kebbi State Polytechnic. The results revealed that there was no significant difference between the post-test and retention-test scores of students exposed to either Challenge-Based Learning or Place-Based Learning, indicating that the knowledge acquired during instruction was substantially retained over time. Furthermore, the study found no significant difference in the retention performance of students taught using Challenge-Based Learning and those taught using Place-Based Learning. This suggests that both instructional strategies possess comparable potential for fostering long-term retention of Computer Architecture concepts. Therefore, the study concludes that learner-centred and context-based instructional approaches such as Challenge-Based Learning and Place-Based Learning can effectively support sustainable learning and retention in Computer Engineering education.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations are made:

1. Computer engineering lecturers should adopt Challenge-Based Learning and Place-Based Learning in the teaching of Computer Architecture and related courses, as both instructional strategies have demonstrated effectiveness in promoting students' retention of learned concepts over time.
2. Curriculum developers and educational administrators should integrate learner-centred and contextualized instructional approaches into Computer Engineering programmes, thereby encouraging the use of authentic

challenges and local real-world contexts that facilitate meaningful learning and long-term knowledge retention.

3. Professional development programmes, workshops, and seminars should be organized for lecturers on the design and implementation of Challenge-Based Learning and Place-Based Learning strategies, to enhance their pedagogical competence and improve the quality of teaching and learning in technical and engineering education.

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