

EFFECT OF LEARNING ANALYTICS-DRIVEN FEEDBACK ON COMPUTER SCIENCE EDUCATION STUDENTS' ACADEMIC ACHIEVEMENT IN DATA STRUCTURES IN PUBLIC UNIVERSITIES IN SOUTH-SOUTH, NIGERIA

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Abstract

This study investigated the effect of learning analytics-driven feedback on Computer Science Education students' academic achievement in Data Structures in public universities in South-South, Nigeria. It was guided by two research questions and two null hypotheses tested at 0.05 level of significance. It adopted a quasi-experimental pre-test, post-test non-equivalent group research design. The population comprised 791 Computer Science Education students, while a sample of 186 CSE students was selected from two public universities using purposive sampling techniques. Data were collected using Data Structures Achievement Test (DSAT) and it was subjected to face and content validation, while its reliability was established through a trial test involving 20 CSE students from a public university in South-South. The trial test yielded a reliability coefficient of 0.83, which was determined using the Kuder–Richardson 20 (KR-20) formula. The DSAT was administered to the experimental and control groups before and after the treatment. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the null hypotheses. The findings revealed that students taught Data Structures using learning analytics-driven feedback achieved a higher mean score than those taught using the conventional lecture method. The findings also showed a difference in the mean achievement scores of male and female students in the experimental group, with male students recording a higher mean achievement score than their female counterparts. In line with the findings, it was recommended that Computer Science Education lecturers should adopt learning analytics-driven feedback to enhance students' achievement in Data Structures.

Keywords: Learning Analytics, academic achievement, Computer Science Education, Data Structures

Introduction

Education is a fundamental process through which individuals acquire knowledge, skills, competencies and values that support personal development, employability and effective participation in society. Martinez et al., (2023) observed that tertiary education and skills development are critical for preparing individuals for changing labour-market demands and supporting productivity and lifelong learning. At the university level, Wang (2023) emphasized that digital transformation requires higher education institutions to integrate digital skills, competencies, values and attitudes into academic programmes. Therefore, universities have an important responsibility

to develop graduates who possess relevant technological competencies and can apply digital knowledge and skills effectively in contemporary workplaces and society, particularly in Computer Science Education. Computer Science Education refers to the systematic teaching and learning of computing concepts, programming, computational thinking, problem-solving and digital skills. Lee et al., (2022) explain that Computer Science Education involves educational approaches that develop learners' computational thinking through programming and other computing activities. Alajlan et al., (2023) further emphasize the importance of appropriate teaching and learning strategies for developing computational thinking in computer

education. Computer Science Education can be understood as the organised process of developing learners' knowledge and skills for understanding, applying and creating computing solutions.

Computer Science Education is important because it develops students' programming skills, computational thinking, problem-solving abilities, and digital competencies needed to understand and apply computing technologies. United Nations Educational, Scientific and Cultural Organization (UNESCO, 2023) explains that computer science education, including coding, programming, computational thinking and problem-solving, contributes to the development of digital skills required for learning, work and participation in society. Computer Science Education includes a fundamental course that develops students' ability to organise, store, retrieve, and manipulate data efficiently for effective programming and computational problem-solving through Data Structures.

Data Structures (DS) refers to systematic ways of organizing, storing, and managing data in a computer so that it can be accessed and processed efficiently. In Computer Science Education, DS is important because it develops students' understanding of fundamental structures such as arrays, linked lists, stacks, queues, trees, and maps, which are essential for effective programming and software development (Kumar et al., 2023). Kumar et al. (2023) further stated that DS supports programming and algorithm design by enabling students to select appropriate ways of organizing data, analyse computational efficiency, and develop effective solutions to problems. The effective teaching and learning of DS can be enhanced through timely, personalized, and evidence-based guidance that helps students identify learning gaps and improve their programming skills through learning analytics-driven feedback.

Learning analytics-driven feedback can be defined as the use of data generated from learners' activities and performance to

provide timely, evidence-based guidance that helps them understand their progress, identify areas requiring improvement, and make informed decisions about their learning (Topali, et al., 2023). Learning analytics-driven feedback refers to the use of data generated from students' learning activities to provide timely, targeted information that helps learners understand their progress and improve their learning. Banihashem et al., (2022) found that learning analytics provides important opportunities for enhancing feedback practices in higher education by using learning data and analytical methods to support both students and educators. Lim et al. (2021) reported that students who received learning analytics-based process feedback demonstrated different self-regulated learning patterns and achieved significantly higher final course marks than students who did not receive the feedback. Iraj et al. (2021) further examined personalised and actionable feedback messages and highlighted the potential of learning analytics to address challenges associated with providing effective feedback to students in higher education. Therefore, learning analytics-driven feedback can provide a data-informed approach to identifying students' learning difficulties, monitoring their progress, and supporting improved academic achievement.

Academic achievement refers to the level of success students demonstrate in attaining intended learning outcomes, usually measured through tests, examinations, assignments, and other classroom assessments. It indicates the extent to which learners are able to acquire, understand, process, retain, and apply knowledge and skills gained through instruction. According to Akanbi et al., (2022), in science education, academic achievement is commonly evaluated using achievement tests and other structured assessment procedures that provide evidence of students' learning and performance. Similarly, Mejía-Rodríguez et al. (2022) explain that student achievement

represents an important measure of educational effectiveness and learning outcomes, making it a significant indicator of students' attainment of academic objectives. Lim et al. (2021) reported that learning analytics-based process feedback improved students' learning progress and academic achievement in a large undergraduate course. Iraj et al. (2021) also found that personalized and actionable feedback supported students by providing targeted feedback based on their learning activities and needs. These studies indicate that learning analytics can strengthen the effectiveness of feedback and support improved student learning outcomes.

Feedback is an important part of teaching and learning because it provides students with information about their performance and guidance on how to improve their learning. Wang and Han (2021) found that process-oriented learning analytics feedback improved students' learning effectiveness, particularly among learners with lower prior knowledge. Similarly, Banihashem et al. (2022) reported that learning analytics can enhance feedback practices in higher education by using students' learning data to support more informed feedback. Kyne, et al. (2023) also found that learning analytics-based personalised feedback emails could support academic performance and student success in large university courses. Therefore, timely, specific, and personalised feedback supported by learning analytics can help students recognise learning difficulties, respond to weaknesses, and improve their academic achievement. Academic achievement can be influenced by various learner and educational factors, including differences in students' learning experiences, opportunities, attitudes, and academic performance associated with gender.

Gender refers to the socially and culturally constructed roles, behaviours, expectations, and identities that influence how males and females experience and participate in educational activities (United Nations

Educational, Scientific and Cultural Organization [UNESCO], 2020; World Health Organization [WHO], 2021). In higher education, gender may be relevant to students' learning experiences, engagement with technology, and academic achievement, particularly in technology-oriented disciplines such as Computer Science Education. Gender in this study is considered in relation to the academic achievement of Computer Science Education students in DS, where students may differ in their engagement with learning technologies and responses to learning analytics-driven feedback. John et al. (2018) examined gender differences in the academic performance of 3,046 undergraduates across STEM-related disciplines in a Nigerian university, including Computer Science, and found evidence of gender-related differences in students' academic performance, thereby demonstrating the relevance of gender when examining academic achievement in Nigerian tertiary education. Oladejo et al. (2021) reported gender-related differences in students' performance when technology-based instructional approaches were used in science learning, suggesting that gender may be relevant when examining students' academic outcomes in technology-supported learning environments. Therefore, examining gender in this study may provide evidence on whether learning analytics-driven feedback produces differences in the academic achievement of male and female Computer Science Education students in DS in public universities in South-South Nigeria. The concern that motivated the researcher is the unsatisfactory academic achievement of some Computer Science Education students in DS, which may be associated with delayed, general, or inadequate feedback that does not enable students to identify and correct learning difficulties promptly. This concern is heightened by the foundational nature of DS, as poor achievement may weaken students' programming and problem-solving abilities and limit their

readiness for advanced courses and computing-related professional activities. Banihashem et al. (2022) observed that learning analytics can enhance feedback practices by helping students monitor their learning progress and identify areas requiring improvement; however, their review did not specifically establish the effect of learning analytics-driven feedback on achievement in DS among Computer Science Education students in public universities in South-South Nigeria. It is based on the above discourse that the present study investigated the effect of learning analytics-driven feedback on Computer Science Education students' academic achievement in DS in public universities in South-South Nigeria.

Statement of the Problem

Ideally, Computer Science Education students in public universities should acquire sound knowledge and practical skills in DS and demonstrate satisfactory academic achievement. Effective teaching of DS should provide students with clear explanations, opportunities for practice and timely feedback that enables them to identify errors, correct misconceptions and improve their understanding of the subject. Lecturers should also be able to monitor students' learning activities and assessment performance and use the information obtained to provide appropriate feedback during the learning process. However, the academic achievement of some Computer Science Education students in DS may remain unsatisfactory when feedback is delayed, general or provided only after formal assessments. This situation may prevent students from identifying and correcting their learning difficulties promptly and may contribute to poor performance in the course.

The problem is of particular concern because DS involves important concepts such as arrays, linked lists, stacks, queues, trees, graphs and algorithms, which require regular practice, problem-solving and timely

guidance. When students do not receive adequate feedback on their learning activities and performance, they may continue to make errors and experience difficulties in understanding and applying these concepts. Poor achievement in DS may limit students' ability to develop the programming and problem-solving skills required for advanced courses in Computer Science Education. If the problem persists, students may complete their programmes without acquiring the level of competence expected for further study and computing-related professional activities. It is therefore necessary to determine the effect of learning analytics-driven feedback on Computer Science Education students' academic achievement in DS in public universities in South-South, Nigeria.

Purpose of the Study

The study examined the effect of learning analytics-driven feedback on Computer Science Education students' academic achievement in Data Structure in public universities in South-South, Nigeria. Specifically, the study investigated the:

1. Effect of Learning Analytics-driven Feedback (LADF) on mean achievement scores of students taught Data Structure;
2. Influence of gender on mean achievement scores of students taught Data Structure using LADF.

Research Questions

The following research questions guided the study:

1. What are the mean achievement scores of students taught Data Structures using LADF and those taught using the conventional lecture method?
2. What are the mean achievement scores of male and female students taught Data Structures using LADF?

Hypotheses

H₀₁: There is no significant difference in the mean achievement scores of students taught Data Structures using LADF and those

taught using the conventional lecture method.

H₀₂: There is no significant difference in the mean achievement scores of male and female students taught Data Structures using LADF.

Research Method

The study adopted a quasi-experimental pre-test, post-test non-equivalent control group research design. Muse and Baldwin (2021) defined quasi-experimental research design as a research approach used to examine the effects of an intervention or programme when participants cannot be randomly assigned to experimental and control groups. The design was considered appropriate because intact classes were used, making random assignment of individual students to experimental and control groups impracticable. The population of the study comprised 791 Computer Science Education students, while a sample of 186 students was selected from four public universities in South-South Nigeria using purposive sampling and intact classes. The population of 791 Computer Science Education students was obtained from the official enrolment records of the selected public universities in South-South, Nigeria, covering students offering the programme during the period of the study.

Of the 186 students, 94 were in the experimental group, while 92 were in the control group. The experimental group comprised 65 male and 29 female students. Data were collected using a lecturer-made Data Structures Achievement Test (DSAT) comprising 20 multiple-choice questions. Each correctly answered item attracted one mark, while an incorrect or unanswered item attracted zero mark. The Data Structures Achievement Test (DSAT) was subjected to face and content validation by three experts, comprising two lecturers in Computer Science Education and one lecturer in Measurement and Evaluation. The experts independently examined the test items for clarity, appropriateness, relevance to the

students' level, and adequate coverage of the Data Structures content and learning objectives. Their observations and suggestions were used to revise the instrument before its final administration. A trial test was conducted using 20 Computer Science Education students from a public university in South-South Nigeria who were not part of the main study, and the DSAT yielded a reliability coefficient of 0.83 using the Kuder–Richardson 20 (KR-20) formula because the items were dichotomously scored.

Before the commencement of the study, permission was obtained from the authorities of the selected public universities in South-South Nigeria. Four public universities were selected, with two designated as the experimental group and two as the control group using intact Computer Science Education classes. A training programme was organised for the lecturers involved in the study. Lecturers in the experimental group were trained on the use of learning analytics-driven feedback, including the use of students' learning activities and assessment performance to provide timely and targeted feedback.

Lecturers in the experimental group were trained to use LADF to improve students' learning of Data Structures. The treatment involved collecting and analysing students' learning activities and assessment results using an existing digital platform. Lecturers used the information to identify learning difficulties, monitor students' progress and provide timely, specific feedback, including corrections, explanations, remedial exercises and recommended learning materials. Lecturers in the control group taught the same Data Structures topics using conventional instructional methods, including explanations, demonstrations, examples and exercises, with feedback provided through their usual classroom practices without systematic learning analytics. Both groups received instruction over the same period and completed the same Data Structures Achievement Test

(DSAT) to determine the effect of the intervention on students' achievement.

Lecturers in the control group were trained to teach Data Structures using the conventional lecture method. Before the treatment, the DSAT was administered to students in both groups as a pre-test to determine their entry-level achievement in Data Structures. The test was scored over 40 marks, with each correctly answered question attracting two marks, while each wrongly answered or unanswered question attracted zero mark. The experimental group was subsequently taught Data Structures using learning analytics-driven feedback, while the control group was taught the same topics using the conventional lecture method for the duration of the treatment. Implementation fidelity was ensured by using the same Data Structures content, instructional duration, and assessment procedures for both groups. The lecturers followed the planned instructional procedures, with the experimental group receiving learning analytics-driven feedback based on students' learning activities and assessment performance, while the control group received conventional lecture instruction. The researcher monitored the teaching sessions to ensure that each group received its assigned instructional method without unnecessary overlap. The same Data Structures Achievement Test (DSAT) was administered to both groups before and after the treatment to ensure consistency in assessment.

At the end of the treatment, the DSAT was re-administered to both groups as a post-test.

Table 1: Mean achievement scores and standard deviations of students taught Data Structures using learning analytics-driven feedback and those taught using the conventional lecture method

Group	N	Pre-test Mean ($\bar{x}$)	Pre-test SD (s)	Post-test Mean ($\bar{x}$)	Post-test SD (s)	Mean Differ en-ce
Experimental	94	18.46	3.82	30.68	4.21	12.22
Control	92	18.21	3.76	24.15	4.37	5.94

Ethical compliance was ensured by obtaining permission from the relevant university authorities before conducting the study. The participants were informed about the purpose of the study, and their participation was voluntary. Their identities and responses were kept confidential, and the data collected were used strictly for research purposes. Both groups were taught the same Data Structures topics, and the test results were handled objectively without manipulation or falsification. The data obtained were analysed using mean and standard deviation to answer the research questions, while analysis of covariance (ANCOVA) was used to test the null hypotheses at the 0.05 level of significance. The mean was used to determine the level of students' achievement, with the group having the higher mean score considered to have higher achievement, while the standard deviation was used to determine the degree of variation in the students' scores. For the ANCOVA analysis, the pre-test achievement scores were used as the covariate, while the post-test achievement scores served as the dependent variable. The null hypothesis was rejected when the calculated p-value was less than 0.05, while the null hypothesis was not rejected when the p-value was greater than or equal to 0.05.

Results

Research Question 1: What are the mean achievement scores of students taught Data Structures using learning analytics-driven feedback and those taught using the conventional lecture method?

The results showed that the experimental group obtained a pre-test mean score of 18.46, while the control group obtained a mean score of 18.21, suggesting that both groups had comparable levels of achievement before the treatment. Following the intervention, the experimental group recorded a higher post-test mean score ($M = 30.68$) than the control group ($M = 24.15$). The experimental group achieved a mean gain of 12.22, compared with 5.94 for the

control group, indicating greater improvement in the achievement of students exposed to learning analytics-driven feedback. Overall, the descriptive results suggest that learning analytics-driven feedback was more effective in improving students' achievement in Data Structures than the conventional lecture method.

Research Question 2: What are the mean achievement scores of male and female students taught Data Structures using learning analytics-driven feedback?

Table 2: Mean achievement scores of male and female students taught Data Structures using learning analytics-driven feedback

Group	N	Pre-test Mean ($\bar{x}$)	Pre-test SD (s)	Post-test Mean ($\bar{x}$)	Post-test SD (s)	Mean Differ- en-ce
Male	65	18.58	3.74	32.42	4.08	13.84
Female	29	18.19	3.96	28.93	4.35	10.74

The results showed that male students obtained a pre-test mean score of 18.58, while female students obtained a mean score of 18.19, indicating relatively similar achievement levels before the treatment. Following the intervention, male students recorded a higher post-test mean score ($M = 32.42$) than female students ($M = 28.93$). Male students achieved a mean gain of 13.84, compared with 10.74 for female students, suggesting greater improvement in achievement among male students exposed to learning analytics-driven feedback. Overall, the descriptive results indicate that

male students demonstrated greater improvement in Data Structures achievement than female students.

Hypotheses

H₀₁: There is no significant difference in the mean achievement scores of students taught Data Structures using learning analytics-driven feedback and those taught using the conventional lecture method.

Table 3: Analysis of Covariance on the mean achievement scores of students taught Data Structures using learning analytics-driven feedback and those taught using the conventional lecture method

Source of Variation	SS	df	MS	F	P-value	Partial Eta Squared	Decision
Pre-test	18.42	1	18.42	1.14	.287	.006	—
Group	1,205.36	1	1,205.36	74.62	< .001	.290	Reject H ₀₁

Source of Variation	SS	df	MS	F	P-value	Partial Eta Squared	Decision
Error	2,955.87	183	16.15				
Total	4,179.65	185					

The ANCOVA result showed that there was a significant difference in the mean achievement scores of students taught Data Structures using learning analytics-driven feedback and those taught using the conventional lecture method, $F(1, 183) = 74.62$, $p < .001$. Since the p-value was less than 0.05, the null hypothesis was rejected.

Therefore, learning analytics-driven feedback had a significant effect on students' academic achievement in Data Structures.

H₀₂: There is no significant difference in the mean achievement scores of male and female students taught Data Structures using learning analytics-driven feedback.

Table 4: Analysis of Covariance on the mean achievement scores of male and female students taught Data Structures using learning analytics-driven feedback

Source of Variation	SS	df	MS	F	P-value	Partial Eta Squared	Decision
Pre-test	12.64	1	12.64	0.82	.367	.118	—
Gender	154.73	1	154.73	10.05	.002	.141	Reject H ₀₂
Error	1,156.41	91	12.71				
Total	1,323.78	93					

The ANCOVA result showed a significant difference in the mean achievement scores of male and female students taught Data Structures using learning analytics-driven feedback, $F(1, 91) = 10.05$, $p = .002$. Since the p-value was less than 0.05, the null hypothesis was rejected. Therefore, there was a significant difference in the academic achievement of male and female students taught Data Structures using learning analytics-driven feedback, with the male students recording the higher adjusted achievement.

Discussion of Findings

The finding showed that students taught Data Structures using learning analytics-driven feedback achieved better academic performance and greater improvement than those taught using the conventional lecture method. This finding suggests that using information about students' learning

activities and assessment performance can help lecturers provide more timely and targeted feedback during the learning process. Lim et al., (2021) support this finding, as their study found that learning analytics-based process feedback influenced students' learning progress and academic achievement in a large undergraduate course. Similarly, the work of Iraj et al., (2021) examined personalized and actionable feedback messages and highlighted the importance of using learning analytics to support students through more targeted feedback. The agreement between the present finding and these studies indicates that learning analytics can provide useful information for identifying students' learning needs and supporting timely instructional intervention. Therefore, the higher achievement observed among students who received learning analytics-driven feedback may be attributed to the

opportunity to receive feedback that is more closely related to their learning activities and performance.

The finding showed that male students taught Data Structures using learning analytics-driven feedback achieved higher academic performance and greater improvement than their female counterparts. This finding indicates that differences in academic achievement may occur between male and female students even when they are exposed to the same instructional approach. John et al., (2018) examined academic performance by gender among 3,046 undergraduates across STEM-related disciplines in a Nigerian university, including Computer Science, thereby providing relevant evidence on gender and academic performance in the Nigerian tertiary education context. The authors' dataset specifically included male and female students in Computer Science and other STEM disciplines, making their study relevant to the present finding. The present finding therefore suggests the need for lecturers to monitor the learning progress of both male and female students and provide additional academic support where difficulties are identified. However, the higher achievement of male students in the present study should not be interpreted as evidence that gender alone determines academic performance, since students' achievement can be influenced by several educational and individual factors.

Implications of the Findings: The findings imply that lecturers should adopt learning analytics-driven feedback in teaching Data Structures to improve students' academic performance and provide timely support based on their learning needs. The higher achievement of male students also highlights the need for lecturers to monitor individual progress and provide appropriate support to both male and female students.

Limitations of the Findings: The findings are limited to the students, institutions, and instructional conditions covered by the study,

which may restrict their generalisation to other settings. Furthermore, the observed gender difference does not establish that gender caused the difference in achievement, as other factors, such as prior knowledge, learning habits, and individual engagement, may have contributed to the results.

Conclusion

The study concluded that learning analytics-driven feedback is an effective approach for improving students' achievement in Data Structures. Students who received learning analytics-driven feedback performed better than those taught using the conventional lecture method. This suggests that using information about students' learning activities and assessment performance can help lecturers provide timely feedback and address students' learning difficulties. The study also found a difference in the achievement of male and female students in the experimental group, with male students recording higher mean achievement scores. Therefore, the use of learning analytics-driven feedback should be encouraged in the teaching of Data Structures, while appropriate support should be provided to students who experience difficulties in the course.

Recommendations

Based on the findings, the following recommendations were proffered:

1. Lecturers of Computer Science Education should adopt learning analytics-driven feedback in teaching Data Structures because it can improve students' academic achievement compared with the conventional lecture method.
2. Computer Science Education departments should provide targeted academic support to female students in Data Structures by identifying their learning difficulties and providing timely feedback to improve their achievement.

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