Development and Evaluation of an Interactive Instructional Package for Teaching Engineering Graphics Skills

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Abstract- Exposure to modern pedagogical approaches and methods with appropriate instructional media can enhance the development of high-level critical thinking and technical skills. This study examined the development of an interactive instructional software package for teaching engineering graphics and evaluated its relative effectiveness on second-year undergraduate engineering students' academic achievement, skill transfer, and retention. In this study, the quasi-experimental, pre-test, post-test, control group design was employed. 45 research participants were sampled, employing two-stage stratified sampling technique, which comprises the simple random sampling to assign students into three groups from the study population and systematic sampling with k = 3 to select 15 students from each group to a control group and experimental groups A and B. The control group was exposed to conventional classroom instruction (CI), group A to computer-aided instruction (CAI); and group B to conventional and computer-aided instructions (CCAIs). A computer-aided learning package on engineering graphics was developed using the Camtasia software package, which served as the treatment instrument. The pre-test and post-test data used for analysis stemmed from a validated Engineering Graphics Achievement Test instrument. Analysis of covariance and Sidak post hoc test statistical analysis of the groups' performance provided the results on the comparative effects of the treatment conditions. Findings indicated significant differences between the academic achievement, skill transfer, and retention of students, exposed to CCAIs, and CI or CAI strategies. When used together, a significant improvement in students' academic achievement, transfer, and retention of engineering graphics skills occurred than either the CI or CAI strategy used alone.

Keywords- Computer-aided learning package; engineering graphics; achievement test; Learning technical skills; pre-test; post-test.

1 Introduction

The necessity to introduce the younger generation to life, transmit value and experience, and develop high-level critical thinking and technical skills that the society treasured had led to the origin of education. In recent times, education has evolved as the primary agent of transformation towards sustainable development. Nations show great concern for education, in particular, tertiary education. Tertiary education, often the apex of educational endeavors, is obtainable after primary and secondary education, in universities, polytechnic, and colleges, among others. Its primary goal is to foster learning, skill acquisition and increase human's capacities to transform their visions for the society into reality (Ajimotokan et al. 2010; Ajimotokan 2018).

Effective teaching and learning are a vital pre-condition for learners to efficiently master new concepts, and develop high-level critical thinking and technical skills to meet learning needs and provide outcomes relevant to the demands of an ever- changing society (Laleye, 2018). The exposure to modern pedagogical approaches and methods with appropriate instructional media and state-of-the-art laboratories among others would enhance the transfer and retention of new concepts, and the development of high-level critical thinking and technical skills (Gambari & Yusuf, 2017; Guney, 2019; Ogunjuyigbe, Ayodele, & Ekoh, 2017; Suleman et al.2017).

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Nevertheless, in various institutions of learning in sub-Saharan Africa, the predominant mode of instruction, in particular, in colleges and universities, has been the conventional classroom instruction (CI). This mode of instruction involves the presentation of material through lecture and demonstration using whiteboard, chalkboard, overheads, PowerPoint, or graphing calculator (Spradlin & Ackerman, 2010; Thompson, 2010).

There have been numerous innovative instructional use of information and communication technology since its advent, and indeed, in transforming various aspects of human endeavours, in particular, in the educational sector for productive learners' learning (Abdulrahaman et al., 2020; Ajimotokan, 2018; Eren & Yılmaz, 2022; Oloyede, Ajimotokan, & Faruk, 2017). Furthermore, the knowledge revolution and growing concerns over improving learners' critical thinking and technical skills, and knowledge required for the 21st-century workforce means technology must drive instruction (Ajimotokan, 2018; Saloom, Elameer, & Jalal, 2018).

Thus, the use of concepts such as e-learning, m-learning, computer-aided instruction (CAI), instructional software package and computer-aided training (Ajimotokan, 2018) among others are becoming new paradigm shift in advancing instructional delivery. Instructional software package, an interactive teaching and learning package for CAI, is one of the most promising instructional strategies; hence, the renewed interest in instructional software for instructional purposes in various institutions of learning. To sustain the pressures of a rapidly changing hi-tech environment in the context of the global and contemporary knowledge economy, and choices of when, where, and how learners' learn, CAI is imperative for providing learners with a life-long knowledge (Ajimotokan, 2018).

CAI is an interactive instructional technique that uses computer facilities and resources to present instructions and monitor the learning process (Yusuf & Afolabi, 2010). CAI is a recent instructional trend for enhancing learners' learning (Yusuf & Afolabi 2010), offering various benefits for both formal and informal learning when properly designed and implemented. It utilises a blend of graphs, texts, sounds and videos for stimulating teaching and learning processes (Fakomogbon, Omiola, Awoyemi, & Mohammed, 2014), which are learner-centred and activity-oriented (Gana, 2013). CAI refers to virtually any class of computer application in instructional settings, comprising drill and practice, simulations, instructional and supplementary exercises, instructional management, database development, programming, and MS applications, among others (Gana, 2013). Teaching using CAI helps educators to dedicate more time to individual learners, influences the decisions of learners on when, where, and what to learn, allows learners to progress on learning at self-paced and work individually or in group. Also, the implications of teaching using CAI include the ability to communicate abstract concepts, skills, and animations of hidden processes (Mills, 2001).

Okorie (2015) investigated the relative effectiveness of instructional software package for teaching chemical bonding on senior secondary chemistry students' interest and achievement. The experimental testing revealed that CAI had a significant effect on students' academic achievement and interest in chemical bonding. The study revealed that CAI software was more effective than the CI in students' academic achievement and interest in chemical bonding. Similarly, Ogunjuyigbe et al. (2017) developed a MATLAB based instructional software for teaching and learning of photovoltaic technology and evaluated its relative effectiveness on the intended learning outcomes of undergraduate students. They reported that the students exposed to the CAI mastered the concept and technical skills of a photovoltaic system quickly. Another experimental study by Li, Yamaguchi, & Takada, (2018) examined the effects of interactive learning materials on learners' self-regulated learning processes and learning satisfaction among primary school teachers. Five self-regulation processes identified were internal motivation, motivation for better assessment, planning and organising skills, critical and positive thinking skills, and effort regulation. They reported that interactive learning materials assisted highly motivated teachers to accomplish better evaluation, and the teachers recorded better learning satisfaction.

A review of the relevant published works in the literature highlighted the gaps in the development of instructional software package and their relative effectiveness for teaching enrolled undergraduate students and the need for continued research and technology development. Furthermore, none of the known published studies attempted the development of instructional software package for teaching engineering graphics skills and its relative effectiveness on academic achievement, skill transfer, and retention of enrolled undergraduate students. Thus, this study examines the development and evaluation of the relative effectiveness of an interactive instructional software package for teaching engineering graphics on second-year undergraduate engineering students' academic achievement, skill transfer, and retention.

1.1 Research Questions

The following research questions guided this study:
i.) Will there be any difference in the post-test achievement scores of students taught using conventional and computer-aided instructions (CCAIs), CAI, and CI?
ii.) Will there be any difference in the retention test scores of students taught using CCAIs, CAI, and CI?

1.2 Research Hypotheses

The following research null hypotheses tested at 0.05 level of significance guided the study.
Hypothesis 1: There will be no significant differences in the students' post-test scores in engineering graphics when exposed to CCAI, CAI, and CI.
Hypothesis 2: There will be no significant differences in the students' skill transfer and retention test scores in engineering graphics when exposed to CCAI, CAI, and CI.

2 Methodology

2.1 Research Design

This study was a pre-test, post-test quasi-experimental control group design. The research design had three levels of treatments, comprising a control and two experimental groups. The control group was exposed to conventional instruction (CI); experimental group A to the computer-aided instruction (CAI) treatment condition; and experimental group B to conventional and computer-aided instructions (CCAIs) treatment condition. The treatment instrument was an interactive CAI on students' academic achievement, skill transfer, and retention in engineering graphics. The instruction mode was the independent variable. At the same time, the engineering graphics achievement, skill transfer, and retention were evaluated using the post-test and retention test, respectively, which are the dependent variables, and the pre-test as the covariate.

2.2 Sample and Sampling Technique

The study population was the faculty of engineering and technology (FET) second-year undergraduate engineering students of a University, North-central Nigeria. This tertiary institution was purposively sampled based on the following criteria: school ownership (i.e. a public institution), information and communication technology facilities (i.e. availability of computer laboratories and workforce), and candidates' enrolment. The nature of this study necessitated that the research sample should be purposively selected because CAI research must be conducted in an institution, which has computer laboratories readily available for students' use. A sample size of 45 selected second-year undergraduate engineering students across the departments of the FET were sampled, employing the two-stage stratified sampling technique. At the first stage, the simple random sampling was used to assign students into three groups from the study population, while the

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systematic sampling with k = 3 was employed to select 15 students (n = 15) from each group to a control group and experimental groups A and B.

In conducting this study, established ethical standards were followed while employing the treatment conditions. First, the sample, consisting of undergraduate students, were informed about the objectives of the study; and they consented and voluntarily agreed to take part in any of the treatment conditions. Second, the treatment for the experimental groups took place in computer laboratories where safety concern issues were a priority (fire extinguisher, adequate space, and first aid, among others). The participant's confidentiality for their participation and performance occurred through unique numbers, which were known to the research team members alone. Finally, data were collected only for relevant components, as earlier agreed with participants.

2.3 Research Instruments

The treatment instrument, an interactive instructional package for teaching second-year undergraduate engineering students graphics skill, was developed using Techsmith Camtasia for interactive computer-aided learning package (CALP) multimedia. The package served as treatment instrument for the two experimental conditions. Students in two different instructional settings, the CAI and the CCAIs strategies, had exposure to the treatment instrument, CALPs on engineering graphics. The CALP is a self-instructional, interactive software package, which lasts for a minimum of 120 minutes for an average student, contains three units (topics), organised into modules of forty minutes each. The topics covered include an introduction to lettering, use of lines, and dimensioning, which are some of the basic general topics from the course outline of any tertiary institution academic programme for engineering graphics.

The Techsmith Camtasia served as the overall platform for the CALP development. Other computer programmes and applications utilised during the development process were AutoCAD 2013 and Microsoft PowerPoint. The AutoCAD 2013, a commercial computer-aided design and drafting software application, was utilised in the drafting and exporting the 2-dimensional designs employing a computer. Microsoft PowerPoint, a presentation software program imbedded in the Microsoft Office package, was utilised in creating the notes and graphical presentations. Camtasia, a software suite for creating interactive videos and presentations, was utilised in creating the video tutorial of the simple AutoCAD design, and the Microsoft PowerPoint presentation video via a direct recording plug-in to Microsoft PowerPoint. The Camtasia software allows the created CALP export to standard video formats, including MPEG-2, MPEG-4, WMV and AVI; which also allows video production in Macromedia Flash format without a programming language. The package contained three topics that are organised into modules. The main menu of the learning package comprises an introduction, student registration, list of modules (i.e. modules one, two, and three), and exit, adopting the drill and practice modes of CAI.

A researcher-developed test instrument, entitled engineering graphics achievement test (EGAT) served as the instrument for data collection from the pre-, post- and retention tests. The test instrument (EGAT) was a 25-item fill in the gap test. The items in the tests were drawn from the contents of the CALP, based on the six levels of the revised Bloom's cognitive domains of learning a table of specification guided the items development. Each of the stems of the 25-item fill in the gap test had one, two or three gaps for possible answers to the question, and each question was worth four points. The EGAT served as a pre-test for the treatments and control groups. The same items were rearranged and re-administered as post-test and retention test. The post-test served to establish the difference between the academic achievement, skill transfer, and retention of students in the control and experimental groups. The pre-, post- and retention tests were administered on the participants to evaluate students' academic achievement, engineering graphics skill transfer and retention.

2.4 Validation of Research Instrument

Experts validated the researcher-developed instruments. The validation entails evaluation by educational technology experts and subject content (engineering graphics) specialists. Afterwards, the CALP and EGAT instruments were administered to 15 randomly selected undergraduate engineering students in their second-year within the FET study population, who were not involved in the study for appearance, operation and logic, spelling, grammar, readability, and clarity from the perspective of persons unfamiliar with the contents.

2.5 Procedure for Data Collection

For data collection, the study objectives and modalities were specified, and an operational guide was produced before the commencement of the treatment on the sampled population. The treatment period covered four weeks for all groups (two hours per week). At the commencement of the study, all the three groups had the EGAT administered on them as the pre-test. After the pre-test, the students in the experimental groups were exposed to treatment using CALP on engineering graphics, installed on desktop computers in the FET computer laboratory and PC. The experimental group B students used combined CI and CALP. The control group students' learnt in the conventional classroom teaching environment. The classroom contained an overhead projector, board, and personal computers, which students used for the instruction. The students in the experimental groups A and B were exposed to the CALP under the tutor's supervision long enough for them to be familiar with the package and use it independently.

With the CAI strategy, students learnt the engineering graphics concepts with the CALP treatment setting. The instruction was presented employing PCs under the tutor's supervision long enough for the students to be familiar, and be capable of utilizing the navigation buttons of the package independently. Afterwards, the students used the CALP on engineering graphics to study at their self-pace. For the CCAIs strategy, the students were exposed to the engineering graphics concepts using the CI (with the same contents of the CALP) and CALP

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using PCs. In contrast, the students of the control group were exposed to the engineering graphics concepts employing the CI only using the same contents as contained in the CALP. At the beginning of each strategy, students answered the EGAT as a pre-test. The control and experimental groups' treatment lasted for three weeks. Then, every group was exposed to the EGAT, rearranged as post-test. Also, at the end of the fourth week, all the groups were exposed to the EGAT as retention test.

2.7 Techniques for Data Analysis

The differences between students' pre-test, post-test and retention test scores for EGAT on a 25-item fill in the gap test were analysed using analysis of covariance (ANCOVA) of the post-test and retention test scores and their Sidak post hoc test to show the direction of differences established in the post-test and the retention test. The ANCOVA and Sidak post hoc test at 0.05 significant level were carried out using IBM Statistical Package for the Social Sciences (SPSS) 25.

3 Results and Discussion

Table 1 presents the descriptive statistics of the pre-test, post-test and retention test scores for the CI, CAI, and CCAIs strategies. The students' mean post-test scores and standard deviations (SDs) for those exposed to CI were 70.40 and 11.14; CAI were 77.33 and 7.39, and CCAIs were 83.47 and 7.11, respectively. The mean retention test scores and SDs for students exposed to CI was 62.93 and 9.22, CAI were 70.00 and 6.41, and CCAI were 76.27 and 6.09, respectively. The overall participants' mean and SD for the post-test score were 77.07 and 10.32, and the overall participants' mean and SD for the retention test score were 69.73 and 9.07, respectively.

Table 1. Descriptive statistics of the pre-test, post-test and retention test scores of students exposed to CI, CAI, and CCAIs

Instructional Strategies	N	Pre-test Mean (SD)	Post-test Mean (SD)	Retention test Mean (SD)
CI	15	13.73 (5.12)	70.40 (11.74)	62.93 (9.22)
CAI	15	20.13 (10.24)	77.33 (7.39)	70.00 (6.41)
CCAIs	15	23.47 (11.07)	83.47 (7.11)	76.27 (6.09)
Total	45	19.11 (9.88)	77.07 (10.32)	69.73 (9.07)

3.1 Testing of the Hypotheses

The null hypothesis one states that there are no significant differences in the students' post-test academic achievement in engineering graphics for those exposed to CI, CAI, and CCAIs. The ANCOVA analysis assumptions are to establish the post-test scores' differential, after the control of the pre-test scores was statistically significant and did not occur perchance. Table 2 presents the summary of the ANCOVA of the students' pre-test and post-test mean scores for those exposed to CI, CAI, and CCAIs strategies.

Table 2. ANCOVA summary of the pre- and post-test mean scores of students exposed to CI, CAI, and CCAIs

Source of Variation	Sum of Squares	Df	Mean Square	F	P-value
Covariates (Pre-Test)	219.44	1	219.44	2.826	00.1
Main Effect (Group)	709.074	2	354.537	4.566	0.016
Explained	1501.574	3	500.525	6.447	0.001
Residual	3183.226	41	77.64		
Total	271952	45			

There were statistically significant differences in the students' academic achievement in engineering graphics using the methods of instruction, F (2, 41) = 4.57, p = 0.02 as reflected in Table 2. Therefore, the null hypothesis one was rejected. There were statistically significant differences between students' academic achievement in engineering graphics, evaluated based on the students' post-test scores for those exposed to CI and CCAIs. Moreover, there were no statistically significant differences between students' academic achievement in engineering graphics, exposed to CI or CAI. In addition, the covariate of pre-test significantly influenced the post-test (dependent variable), F (1, 41) = 2.83, p = 0.1 as reflected in Table 2. Based on the established significant differences in the experimental and control groups' post-test achievement scores, Sidak's test was carried out for post hoc analysis to establish the direction of the differences.

Table 3 presents the post hoc analysis of the mean post-test achievement scores of students exposed to CI, CAI, and CCAIs. Table 3 depicted that there was no significant difference in the students' post-test mean scores for those exposed to CI and those of CAI. A significant difference was established between CCAIs, and CI or CAI used alone.

Table 3. Sidak's post hoc pairwise comparisons of mean post-test achievement scores of students exposed to CI, CAI, and CCAIs

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval Difference Lower Bound	95% Confidence Interval Difference Upper Bound
CCAIs	CAI	5.305	3.255	0.297	-2.798	13.407
	CI	10.647*	3.525	0.013	1.873	19.421
CAI	CCAIs	-5.305	3.255	0.297	-13.407	2.798
	CI	5.342	3.354	0.316	-3.006	13.69
CI	CAI	-5.342	3.354	0.316	-13.690	3.006
	CCAIs	-10.647*	3.525	0.013	-19.421	-1.873

* - The mean difference is significant at the 0.05 level.
a - Adjustment for multiple comparisons: Sidak.

The academic achievement of the students was also compared on the basis of the groups' pre- and post-test mean scores, and their mean gain scores of those exposed to the CI, CAI, and CCAIs instructional strategies. Figure 1 depicts the comparison of the groups' pre- and post-test mean scores, and the mean gain scores of students exposed to CI, CAI, and CCAIs. The CCAIs had the highest increase with a mean gain score of 23.47, followed by CAI with a mean gain score of 20.13, and CI with a

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mean gain score of 13.73. These indicate that students mostly learnt the engineering graphics concepts when exposed to CCAIs.

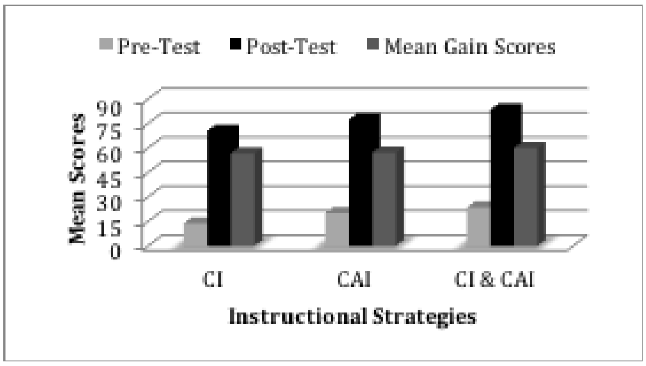

Fig. 1: Comparison of the pre- and post-test mean scores, and mean gain scores of students exposed to CI, CAI, and CCAIs

The null hypothesis two was stated as follows: there are no significant differences in the students' skill transfer and retention test in engineering graphics for those exposed to CI, CAI, and CCAIs. Similarly, the instruction method was the independent variable while engineering graphics achievement, established based on the retention test was the dependent variable, and the post-test was the covariate. The SPSS was utilised for the ANCOVA at 0.05 significant level. Table 4 presents the summary of the ANCOVA of students' post-test and retention test mean scores for those exposed to CI, CAI, and CCAIs.

Table 4. ANCOVA summary for the post-test and retention test mean scores of students exposed to CI, CAI, and CCAIs

Source of Variation	Sum of Squares	Df	Mean Square	F	P-value
Covariates (Post-Test)	2143.284	1	2143.284	616.306	< 0.0001
Main Effect (Group)	47.873	2	23.936	6.883	0.003
Explained	3478.217	3	1159.406	333.389	< 0.0001
Residual	142.283	41	3.478		
Total	222444	45			

There were statistically significant differences in students' engineering graphics skill transfers and retention using the methods of instruction, $F(2,41) = 6.88$, $p = 0.003$ as reflected Table 4. Therefore, the null hypothesis two was rejected. There were statistically significant differences between students' engineering graphics skill transfer and retention, evaluated based on the students' retention test scores for those exposed to CI, CAI, or CCAIs strategies. The retention test mean score for CCAIs was the highest and its considerably higher compared with the retention test mean score for CAI or CI. Furthermore, the covariate of post-test significantly influenced the dependent variable of the retention test, $F(3, 41) = 2.84$, $p < 0.0001$ as reflected Table 4.

To evaluate the students' engineering graphics skill transfers and retention of the three groups, the students' academic achievement of the control and experimental groups were further compared on the basis of the mean loss scores between the post-test and retention test for the CI, CAI, and CCAIs instructional strategies. Table 5 presents the post hoc analysis of the students' retention test mean scores for those exposed to CI, CAI, and CCAIs. Table 5 depicted a decrease in retention test mean scores for the three instructional strategies as compared to their mean post-test scores.

Table 5: Sidak's post hoc pairwise comparisons of mean retention test scores of students exposed to CI, CAI, and CCAIs

(I) Group	(J) Group	Mean Diff. (I-J)	Std. Error	Sig.[a]	95% Confidence Interval Difference Lower Bound	95% Confidence Interval Difference Upper Bound
CCAIs	CAI	1.399	0.709	0.156	-0.365	3.163
	CI	2.963*	0.799	0.002	0.974	4.951
CAI	CCAIs	-1.399	0.709	0.156	-3.163	0.365
	CI	1.564	0.716	0.101	-0.219	3.347
CI	CAI	-1.564	0.716	0.101	-3.347	0.219
	CCAIs	-2.963*	0.799	0.002	-4.951	-0.974

* - The mean difference is significant at the 0.05 level.
[a] - Adjustment for multiple comparisons: Sidak.

The students' engineering graphics skill transfers and retention were also compared on the basis of the groups' post-test and retention test mean scores, and the students' mean loss scores for those exposed to CI, CAI, and CCAIs. Figure 2 depicts the comparison of the students' post-test and retention test mean scores, and the students' mean loss scores for those exposed to CI, CAI, and CCAIs. The CCAIs had the lowest decrease of a mean loss score of 7.20, followed by CAI of 7.33, and CI of 7.47. These indicated that all the students still largely retained the engineering graphics skills they experienced.

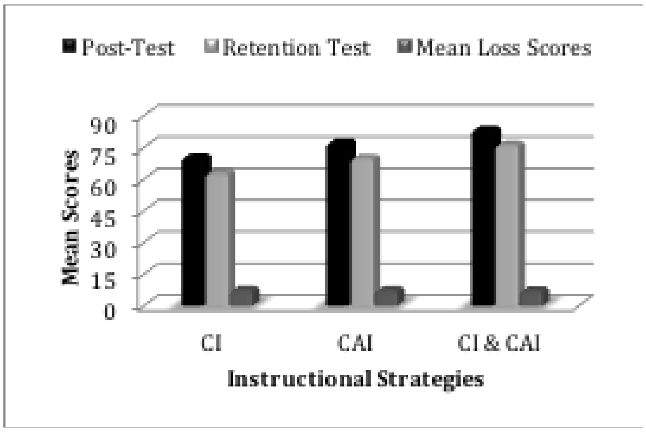

Fig. 2: Comparison of the post-test and retention test mean scores, and mean loss scores of students exposed to CI, CAI, and CCAIs

3.2 Discussion

The analysis of covariance (ANCOVA) depicted that there were statistically significant differences in favour of the students in the experimental groups A and B; that is, those exposed to CAI and CCAIs, respectively. The Sidak test depicted that there were significant differences between the students' post-test achievement and retention for those exposed to CCAIs and CAI. Furthermore, the students exposed to CCAIs did better than those exposed to CAI, as reflected by the higher group mean. Moreover, within the control and experimental groups, there were significant differences established in favour of the experimental conditions, the

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CCAIs and CAI groups. These findings compared favourably with earlier findings reported by Attia and Elsamahy (2004) that students' achievement, when exposed to CAI, was significantly feasible as CI in teaching computer-aided design skills, which is a concept in engineering graphics.

Similarly, the findings compared favourably with the those reported by Yusuf and Afolabi (2010) on biology, Stultz (2013) on mathematics, and Nkemdilim and Okeke (2014) on ecological concepts in biology. These findings suggested that CAI had been an effective teaching and learning strategy in enhancing academic achievement, skill transfer, and retention of students than the CI. These findings are also, supported by those reported by Gambari and Yusuf (2017) on physics, Inuwa, Abdullah, & Hassan (2017) on finacial accounting, and Kasatkina, Masclet, Boujut, & de Vries (2021) on undertanding graphical representations in engineering education but contradict those by Mills (2001). Thus, the finding reveals that the significant difference observed can be attributed to unusual nature of CAI learning strategies.

4 Conclusions

In this study, the development and evaluation of the relative effectiveness of an interactive instructional software package for teaching engineering graphics on undergraduate engineering students' academic achievement, skill transfer, and retention were examined. The study sample was selected based on the two-stage stratified sampling technique, comprising the simple random sampling and systematic sampling with k = 3 into the control and experimental groups. A computer-aided learning package on engineering graphics and engineering graphics achievement test served as the treatment instrument for teaching and test instrument for data collection, respectively. Two null hypotheses were formulated, tested at a significance level of 0.05, and analysed using analysis of covariance and Sidak post hoc test. The instructional strategy, i.e. conventional and computer-aided instructions (CCAIs) had a positive impact on students' academic achievement, engineering graphics skill transfer, and retention compared to those exposed to either conventional instruction (CI) or computer-aided instruction (CAI) only. These suggest that when the teaching strategies are compared, CI was as effective as CAI in students' academic achievement, transfer and retention of engineering graphics skills. However, when used together, a considerable improvement was observed in students' academic achievement, engineering graphics skill transfer and retention than either CI or CAI strategy used alone.

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