The Effect of Three Instructional Elements on Achievement in Computer-Based Mathematics Instruction of Senior Secondary School Students in Nigeria

Tayo Omoniyi *
Gisanrin Gbenga **

Abstract

This study investigated the effect of three instructional elements on achievement in computer-based mathematics instruction. The subjects were senior secondary school students who used four versions of computer-based instruction developed on compact disc to learn about the volume of solid shapes. The four versions of the programme were (1) a full version that had the three instructional elements (2) a version without objectives (3) a version without practice (4) a version without examples. The results indicated that the full package, which included objectives, practice and examples, had a significant effect on students' achievement in the computer-based mathematics instruction. Furthermore, of the three elements, practice, had the most effect on the learners' achievement. Implications of the findings on development of computer-based instructions are also discussed.

Keywords: Computer-based Instruction, Mathematics education, Instructional elements, Students' achievement.

Introduction

Information and Communication Technology (ICT) has become a significant factor in the way we learn, communicate, govern ourselves and do business. Indeed, Information and Communication Technology is a driving factor in the process of globalization. ICTs have revolutionized the teaching and learning process by increasing access through the use of a great variety of educational resources and enabling participatory pedagogies. The use of ICTs in education provides the learners with a more suitable environment to learn, serves to create interest and a learner-centered atmosphere, and helps to increase student's motivation (Serin, 2011).

Computer-Based Instruction (CBI) in an example of how Information and Communication Technologies are integrated into the teaching and learning process. A pedagogical technique that is computer-driven is defined as Computer-Based Instruction. As most modern Information and Communication Technologies are computer-driven, ICT utilization in teaching and learning process is often defined as Computer-Based Instruction. The use of CBI helps students to process and develop information, take an active part in the learning process and develop their problem-solving skills. According to Chang (2002), computer-based instruction is far more effective than the traditional teaching methods, as it is effective in presenting information, testing, evaluation and providing immediate feedback.

CBI enables learners to progress at their own pace and provides them with appropriate alternative ways of learning by individualizing the learning process (Senemoglu, 2003). As a multi-media approach to instruction, CBI provides drawings, graphics,

* Ph.D. Science and Technology Education Department, Faculty of Education, Olabisi Onabanjo University, Ogun State, Nigeria
E-mail: omoniyi2004@gmail.com
** M. Ed., Babcock University High School, Ilishan, Ogun State, Nigeria
E-mail: gisanrinolugbenga@gmail.com

animation, music and other varieties that make its lesson presentations very exciting to learners, particularly because by utilizing this multi-media approach, abstract concepts are concretized for the ease of understanding.

Theoretical Framework

The theoretical basis of this study is Criterion Reference Instruction (CRI) developed by Robert Mager, a behaviorist. The theory is a comprehensive set of steps for design and delivery of instructional programme. The concept makes learning self-instructional. Some of the critical aspects of the theory, according to Mager (1988), include:

1. **Task Analysis:** This requires identification of what needs to be learned, a need assessment level.
2. **Performance Objectives:** Specification of instructional outcomes, i.e. what has to be accomplished and how it has to be evaluated (the criterion).
3. **Criterion-referenced Testing:** Evaluation of learning outcomes, in terms of knowledge specified in the performance objectives.
4. **Modules:** Development of learning modules relating to specific objectives.

CRI is based on ideas of mastery learning. It also incorporates many ideas of Gagne's conditions of learning, including task hierarchies. The major contribution of Criterion Reference Instruction to programmed instruction, including computer-based instruction, is the stress on formation of objectives in a clear and specific manner before progressing to organize instructions.

According to Owusu, Monney, Appiah and Wilmot, (2010), the use of computer-assisted instruction, especially in tutorial mode, is supported mostly by the Behaviorist view of learning, largely due to the principles of objective, practice and reinforcement.

This study made use of the criterion-referenced instruction, derived from the practices of Robert Mager's behaviorism. The activities were presented in graded steps as recommended in task analysis. The students had the opportunity of being active in the learning process, and receiving immediate feedback. Students also worked at their own pace. The critical guide derived from the work of Robert Mager and other behaviorists is that the elements of instruction are expected to be incorporated into any version of the instructional programme, computer-based instruction inclusive. The elements that were directly incorporated into this study were objectives, examples and practice. Reviewed literature on each of the elements are presented below. It must be noted that instruction, though not manipulated, was a component of all the versions of this programme.

Objectives

An Instructional objective is a statement that describes what learners are expected to do or to be able to do once the process of classroom instruction is over. According to Mager (1988), instructional objectives are best described in terms of the terminal behaviour expected form the learners. It describes the intended outcome of instruction in behavioral (measurable) terms.

Studies have reported that when students know what will be expected of them, they tend to perform better. For instance, research on effectiveness of objectives in computer-based cooperative learning reported that the students who were exposed to the instructional objectives performed significantly better on post-test items than those who received either advanced organizers or no orientation activities (Klein & Cavalier, 1999). Researchers have also found that objectives do not produce significant

difference in learning (Martin, Klien & Sullivan, 2007). Hannafin (1987) reported that the presence of objectives systematically introduced into a computer-based instruction did not significantly influence performance in the lessons presented.

Instruction

Instruction describes detailed information or directives on how something should be done or processed. According to Forcier and Descy (2002), every learning environment has an implied method of information presentation. Instruction also refers to the process or act of imparting knowledge. During the process of instruction, students encounter the content to be learnt, either in the didactic form or through a process of discovery (Martin et al, 2007).

In computer-based instruction, instruction includes processes for presenting educational information to students. The teacher or instructional designer frames such information, rules or principles to guide exploration of the material by the students. Such instructions aimed at aiding the tasks stated in the CBI objectives are explicitly presented.

Practice

Practice is defined as the event of instruction provided to learners after they have been given the information required to achieve an objective (Gagné et al., 1988). Practice involves asking learners to perform the given tasks. In computer-based instruction, practice provides feedback on learners' understanding of the concepts taught and reinforces retention.

Studies have reported that practice significantly affects academic achievement. Philips, Hannafin and Tripp (1988) found a significant difference favoring practice over no practice in an interactive video in which practice items were embedded questions. Yeo and Neal (2004) examined the relationship between motivation and performance during skill acquisition practice. It was reported that the relationship between effort and performance increased with practice.

Examples

Examples are verbal or graphical information that provides additional clarification of rules and information presented to leaners. Examples, graphical representation and analogies are some of the guidance strategies used in clarifying content in computer-based instruction. According to Sweller, Krischner and Clark (2007), examples are so significant in academic achievement that they are rated as the best known and widely studied of the elements regarding cognitive load effects. Examples are said to improve learning by reducing cognitive load during skill acquisition.

Purpose of the study

The wide use of computer-based instructional packages, particularly in contemporary time, requires that elements of instructional design are included in their development. Most studies had examined single instructional element for effect, although a few had combined the elements. In general, studies have reported that presence of these elements resulted in positive effects on student learning outcomes. It is pertinent to examine the likely outcomes of a combination of these elements in a programme on academic achievement of students in Nigerian secondary schools, with their infrastructural deficiency for the use of such technologies.

Therefore, this study examined the effect of objectives, examples and practices when they are systematically combined in a computer-based instruction. The question which guided this study was "which of the instructional elements investigated in this study significantly affected achievement?"

Methodology

Research Design

This quasi-experimental study used the pretest/posttest control group design. The mixed design is one of the most widely used designs in experimental studies.

Sample

The participants were 60 senior secondary school (SSI) students. Purposive sampling technique was adopted in selecting the sixty participants from SS1 mathematics classes, of four (4) senior secondary schools in Ikenne and Ijebu-Ode local government areas of Ogun State, Nigeria. The participants were of secondary schools with functional, well-equipped computer laboratories and fair background knowledge of computer usage.

Instruments

Computer-based instruction (CBI) on the next topic in mathematics was applied in the class. The scheme of work i.e., the "volume of solid shapes", was developed. An introduction section was included in the programme and operations of the CBI explained in details.

Subsequent sections introduced the concept i.e. the other four sections described formulae for surface area and volume of solids, such as cuboids, prism, pyramid, cone, cylinder and sphere. Examples and related exercises were also included. The CBI was pilot-tested with fifteen students of a secondary school which did not participate in the main study.

The material was designed in four different versions that included combinations of the elements. The four versions consisted of: (1.) A programme with objectives, practice and examples (2.) A programme without objectives (3) a programme without examples (4) a programme without practice.

The instrument for the study - "Computer-Based Instruction Test" (CBIT) - consisted of 30 objective items. The content was drawn from field-validated past questions of the West African Senior Secondary School Mathematics Examination, 2001-2008.

Validation

To ascertain the reliability of the adapted instrument, a draft of initial fifty (50) items was administered on fifteen students of a senior secondary school (SS1), different from the participating in the quasi-experiment schools.

From the responses of the students, discrimination and difficulty index was used to remove twenty of the items. Eventually, thirty (30) items consisted of the content of the CBIT.

A test-retest technique was adopted to elicit the data for reliability of the instrument. Kuder Richardon 20 (KR-20) was used to determine the reliability coefficient of the instrument, which was found to be 0.72. The CBIT was administered as pre-test. The post-test consisted of a reshuffled version of the same 30 – item test.

The next topic in the scheme of work (volume of solid shapes) was selected and a lesson prepared on four compact discs of thirty modules each, 10 modules per lesson. Copies of the disc were made and individual students interacted with the disc, using the assigned computer in the laboratory, under the guidance of trained assistants who functioned as facilitators.

The participants in each school were given copies of a version of the computer-based instruction relating to the group they have been randomly assigned, i.e. full package, without objectives, examples and practice. All four groups followed the same procedure as detailed in the information provided as preamble to the content of the CBI.

At the end of the three weeks of treatment, the four groups were administered the CBIT, earlier used as pre-test.

Data Analysis

The data were preliminary analyzed using descriptive statistics, while Analysis of Covariance (ANCOVA) was used to analyze the data for statistical difference.

Results

Preliminary Analysis of Data

Table 1. Descriptive Statistics of Students' Achievement in Computer-Based Instructions

Treatment	Mean	Std. Deviation	N
Full Package	21.0667	3.88158	15
Without Examples	17.8000	2.39643	15
Without Objectives	19.8667	2.35635	15
Without Practice	17.4000	1.18322	15
Total	19.0333	2.97997	60

The results in table 1 revealed that participants in the full package group had a mean score of 21.0667 with a standard deviation of 3.88158, whereas participants in the group without examples had a mean score of 17.8000 with a standard deviation of 2.39643. The participants in the group without objectives had a mean score of 19.8667 and a standard deviation of 2.35635, while the participants in the group without practice had a mean score of 17.4000 with a standard deviation of 1.18322.

Table 2. Test of Between-subject Effects of Achievement in Students' Achievement in Computer-Based Instructions

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	314.663[a]	4	78.666	20.675	.000
Intercept	226.100	1	226.100	59.423	.000
pretest	179.397	1	179.397	47.149	.000
Treatment group	86.823	3	28.941	7.606	.000
Error	209.270	55	3.805		
Total	22260.000	60			
Corrected Total	523.933	59			

a. R Squared = .601 (Adjusted R Squared = .572)

b. Covariates appearing in the model are evaluated at the following values: pre-test = 15.5667.

The results in Table 2 indicated that there was a significant effect of the three instructional elements on students' achievement in computer-based instructions ($F_{(3,55)} = 7.606$; $p < .05$). The hypothesis which stated that there is no significant effect of three instructional elements on students' achievement in computer-based instructions was rejected by the findings of this study. The implication of the findings was that instructing students with the three instructional elements will significantly impact on their achievement in computer-based instructions.

Table 3. Test of Between-subject Effects of Achievement in Students' Achievement in Computer-Based Instructions

(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Full Package	Without Examples	2.278*	.727	.017	.289	4.267*
	Without Objectives	.630	.717	1.000	-1.333	2.592
	Without Practice	3.020*	.718	.001	1.054	4.987*
Without Example	Full Package	-2.278*	.727	.017	-4.267	-.289*
	Without Objectives	-1.648	.715	.149	-3.605	.308
	Without Practice	.742	.714	1.000	-1.212	2.696
Without Objective	Full Package	-.630	.717	1.000	-2.592	1.333
	Without Examples	1.648	.715	.149	-.308	3.605
	Without Practice	2.391*	.712	.009	.441	4.340*
Without Practice	Full Package	-3.020*	.718	.001	-4.987	-1.054*

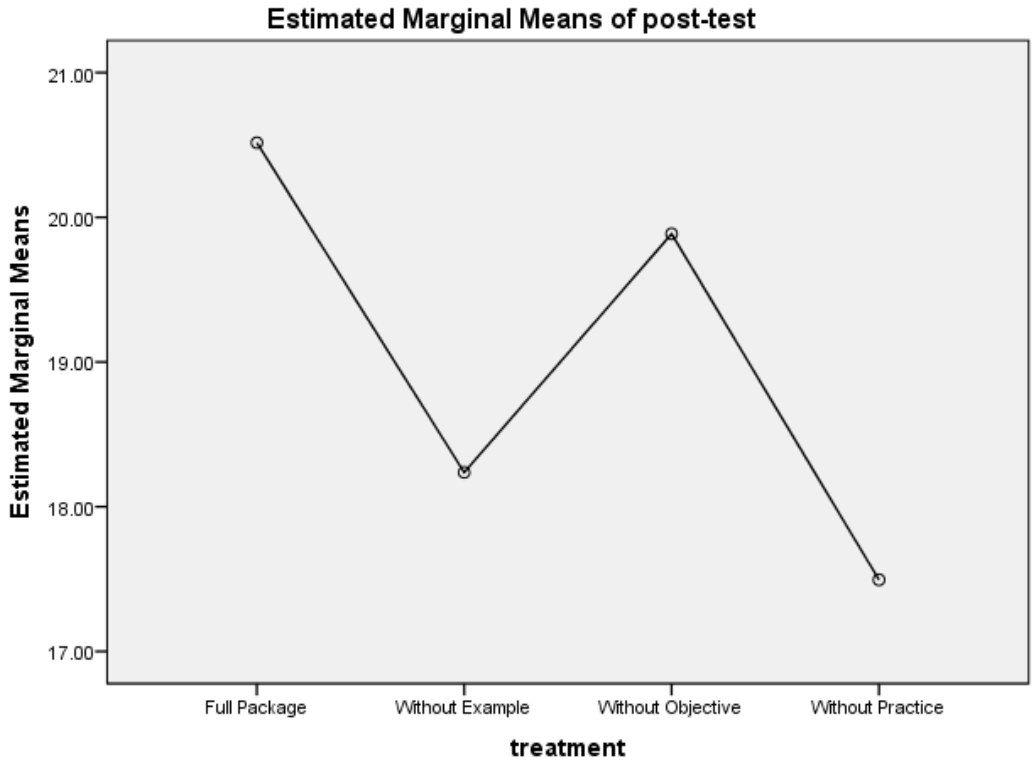
Without Examples	-.742	.714	1.000	-2.696	1.212
Without Objectives	-2.391*	.712	.009	-4.340	-.441*

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

The results in Table 3 showed that the full package has a significant effect on students' achievement in computer-based instructions over and above those in the group without examples (MD = 2.278; std error = .727; $p < .05$). Also the full package has a significant effect on students' achievement in computer-based instructions over and above those in the group without practice (MD = 3.020; std error = .718; $p < .05$). Again, the package without objectives has a significant effect on students' achievement in computer-based instructions over and above those in the group without practice (MD = 2.391; std error = .712; $p < .05$). In effect, withdrawing the elements of objectives, practice and examples from the instructional package has detrimental effects on students' achievement in computer-based instructions. Withdrawing the element of practice is, however, more detrimental on students' achievement in computer-based instructions than withdrawing the element of example. The results are graphically illustrated in Figure 1.



Covariates appearing in the model are evaluated at the following values: pre-test = 15.5667

Discussion and Recommendations

This study examined the effect of three instructional elements (examples, objectives & practice) on achievement in secondary school mathematics. Instructions were stored on compact disc and copies made for students to access and study, using computers in the schools' laboratories.

Results indicated that the full package which included the three elements (objectives, practice & examples) had a significant effect on the students' achievement in the computer-based mathematics instruction when compared with those in the groups without examples, objectives and practice. This finding is in agreement with the result of a similar study (Serin, 2011) which reported that computer-based instruction significantly increased students' achievement and problem-solving skills in science and technology. The finding is also in agreement with the results of similar studies reported by Martin et al. (2007) and Dogan (2010). Furthermore, practice had the greatest effect on the learners' achievement, as participants who had exposure to a version of the computer-based instruction that included practice performed significantly better on the post-test than the group with a version that excluded practice. The exclusion of the two elements (object & examples) did not have such an effect.

Typical of the self-instructional package, practice in this study allowed for feedback to learners' responses, this is aside the opportunity provided learners to do tasks similar to the one being assessed. Findings also indicated that each of the instructional elements had a significant effect on students' achievement in this study. However, examples are another element the withdrawal of which affected students' achievement quite significantly.

The findings have implications on the design and development of computer-based instruction. Although only three elements of instruction (objectives, examples & practice) had their effect investigated in this study, it does not imply that other elements such as information and review are less important. However, it is being recommended that the three elements examined for effect must be included in the design and development of computer-based instructions. Similarly, the potentials of practice as an element with a significant impact must be maximally explored in the design of CBI.

This study was carried out in Nigeria, a developing nation, with a weak infrastructural base for the use of computer-based instruction, including erratic power supply. This explains why the instruction had to be developed using a compact disc, not the web, as done by most other similar studies. It is important to stress this peculiarity of developing countries to appreciate their limitations in the use of computer-based instructions. It therefore implies that this study may be replicated in Nigeria and other developing countries when such instruction is web-based. Further research may also include the instructional elements such as information and review. Students' attitude to web-based instruction and computer-based instruction stored on a compact disc could also be investigated, particularly in Africa and other developing countries where such studies could assist instruction designers.

References

Chang, C.Y. (2002). Does computer-assisted instruction, problem solving improve science outcomes? A pioneer study. *The journal of Education Research,* 95 (3), 143-150.

Dogan, N. (2010). The effect of computer assisted statistics instruction on achievements and attitudes toward statistics. *Education and Science, 34 (154), 3-16.*

Forcier, R.C & Descy, D.E (2002). *The Computer as an Educational Tool (3rd ed).* Upper Saddle River. NJ: Merrill/Prentice Hall.

Gagné, R., Briggs, L. & Wager, W.1988. *Principles of Instructional Design*. Holt, Rinehart & Winston: New York.

Hannafin, M. (1987). The effects of orienting activities, cueing and practice or learning of computer-based instruction. *Journal of Educational Research,* 81 (1), 48-53.

Klein, J.D. & Cavalier, J.C. (1999). *Using Cooperative learning and objectives with computer-based Instruction*. Paper presented at the Annual convention of the Association for Educational Communications and Technology. Houston, Texas.

Mager, R. (1988). *Making Instruction Work*. Belmont, C.A. Lake Publishing Co.

Martin, F., Klien, J.D. & Sullivan, H (2007). The impact of instructional elements in comp uter-based instruction. *British Journal of Educational, Technology,* 38 (4) 623-636.

Owusu, K.A., Money, K. A., Appiah, J.Y., & Wilmot, E.M. (2010). Effects of computer-assisted instruction on performance of senior high school biology students in Ghana. *Computer & Education*. 55, 904-910.

Philips, T., Hannafin, M., & Trip, S. (1988). The effects of practice and orienting activities on learning from interactive video. *Educational Communication and Technology Journal*. 36, 93-102.

Senemoglu, N. (2003). *Development Learning and Teaching*. Ankara: Gazi Publishing.

Serin, O. (2011). The effects of the computer-based instruction on the achievement and problem solving skills of the science and technology students. *The Turkish Journal of Educational Technology*. 10 (1), 183-199.

Sweller, J., Krischner, P. A., & Clark, R, E. (2007). Why minimally guided teaching techniques do not work. *Educational Psychologist,* 42 (2) 115-121.

Yeo, G.B. & Neal, A. (2004). A multilevel analysis of effort, practice, and performance: effects; of ability, conscientiousness, and goal orientation. *Journal of Applied Psychology,* 89, 2, 231-247.