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Effect of Computer-Assisted Instruction in Simulation Mode for Learning Mathematics on students at Secondary school level

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Abstract - Even though mathematics is a prerequisite for higher studies, students in secondary school struggle with maths and frequently ignore the subject. Computer simulations and models have been shown in several studies throughout the world to be an effective computer-based learning environment that helps students develop a deeper understanding of mathematical concepts. The researcher created a computer simulation model based on the Kerala State Secondary School mathematics curriculum and assessed the impact of CAI in simulation mode (CAI-S) on Achievement and Motivation in learning Mathematics. A quasi-experiment was conducted with a single group pre-test-post-test design on 31 students at the Secondary School level based on total sample and sub-sample gender. The findings of the study revealed that CAI-S is effective in enhancing Achievement and Motivation in learning Mathematics among students at Secondary School level. Gender difference was not found in Achievement. Gender difference was found for Motivation in learning Mathematics.

Keywords – *Computer Assisted Instruction, Simulation, Achievement, Motivation, Gender influence.*

1. Introduction

Background of the study

Education Commission (1964-66) of India suggested Mathematics as a compulsory subject for all school students. As a result, mathematics has a special place in the school curriculum. According to Kiamanesh (2006), mathematics is more than just a subject in the school curriculum; it is also a collection of information and skills applied in everyday life, is vital and valuable to everyone, regardless of gender and social level, or background. Many school students struggle with maths and frequently ignore the subject despite this. One of the main reasons for this is that teachers frequently ignore the correct methodology of teaching mathematics and fail the proper integration of technology. Teaching mathematics to impressionable young brains is a specialized undertaking that many mathematics teachers may not be capable of performing.

Even though mathematics is a prerequisite for higher studies, students in secondary schools of Kerala secured the least number of A+ in Mathematics for Secondary School Leaving Certificate Examinations (SSLC) in 2021. So more effort has to be put into the teaching-learning of Mathematics. Students exposed to various computer-assisted instructional learning methodologies will considerably increase their performance in subjects. (Yusuf et al., 2012)

When looking at the Indian education system, it is clear that face-to-face instruction primarily focused on a teacher-centered learning environment is the most popular method of instruction (Faryal Khan, n.d.). With an increase in technology, the integration of ICT into education is also occurring at a tremendous rate. Such changes in instruction bring about paradigm shifts with new endeavours and attempts to use computers and internet more and more. So computers are used for effective communication, improving the teaching-learning process's efficiency, and creating new digital tools and techniques for education. It is also a visual aid used to concretize abstract ideas through simulations, animations, and multimedia, which helps create and reconstruct concepts. Computers can be used in classrooms and self-learning, and self-regulatory learning. Researchers in Computer-Assisted Instruction supports the use of computers in the education system. Computer-Assisted Instruction (CAI) software is designed and used in various ways: drill and practice, tutorial, games, simulations, problem-solving, and discovery. Of the various modes, simulations have been practical for many subjects and classes, especially science and mathematics.

A simulation is an instructional method that allows students to learn tasks as if they were in a natural environment while also practicing problem-solving abilities (Husain, 2010). In simulations, students learn from the consequences of their actions. The individuals can feel the effects of their decision because the environment responds in full. They experience the consequences of their choices and engage in self-corrective behaviour. Interactions can be recorded and analyzed, which will provide feedback to

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the students. It is a very sophisticated computer application, and educational institutions can benefit from this type of software.

Students are given the ability to change different features of models or scenarios. They immediately see the repercussions of their decisions. Higher-order thinking skills are addressed and developed in simulation software.

Need and significance of the study

Computer simulations are a learning model which is student-centered develops broad knowledge, deep understanding, and skills through active and motivated learning. It brings a variety to the typical classroom teaching of mathematics and makes the students more responsible for their own learning. Students transform from passive information receivers to active, self-directed self-learners and problem solvers in computer simulations. It also switches educational programmes' emphasis from teaching to learning. It capacitate the students to acquire new knowledge by making their own decisions and facing the consequences through self-correction. Because this program can make the implausible, believable, and impossible feasible, having pupils complete previously deemed impossible is a powerful method to make learning enjoyable (Walsh, n.d.).

The advent of computer-based learning environments along the objectivistic approach was programmed teaching, tutorials, and drill-and-practice, while Computer simulation is closely related to a type of constructivist learning known as discovery learning (Husain, 2010). Computer simulations and models have been shown in several studies throughout the world to be an effective computer-based learning environment that helps students develop a deeper understanding of mathematical concepts. Given the fact that these approaches have been proven to be effective, they are implemented less in mathematics classrooms of Kerala. Research on the effectiveness of simulations in teaching mathematics in India is also limited in number. Based on these findings, the current study looked at the impact of a CAI method based on simulation mode on secondary school mathematics students' performance.

Statement of the problem

Many books, handouts, and other resources provide a plethora of mathematical information, but getting the most out of them is tough. Textbooks today frequently include DVDs or a link to a website with a simulation library. The lack of access to mathematical software that is specifically connected to the school mathematics curriculum is a difficulty that teachers face. While many instructors find using simulations in the classroom intriguing, little research has been done to see if simulations help a student's knowledge of a subject, particularly mathematics. In this setting, the researcher created computer simulation models based on the Kerala State Secondary School mathematics curriculum and assessed their impact on students. Hence the study is entitled as ***Effect of Computer-Assisted Instruction in Simulation Mode for Learning Mathematics on students at Secondary school level.***

Definition of Key terms

Effect: According to Oxford Learner's Dictionary Effect means the intended change/result produced by something.

Computer-Assisted Instruction in Simulation Mode: It is a mode of Computer Assisted Instruction in which computer software is used to provide simulations through which a learner gets information about a topic by interacting with the computer to gain a deeper understanding of the topic. Learners manipulate parameters of the simulated environment, make choices and see consequences. In the present study CAI in Simulation mode is implemented in Individual settings in a computer laboratory (CAI - S)

Mathematics: According to the Oxford Advanced Learner's Dictionary of Current English, Mathematics is the science of numbers and shapes. (Wehmeier7, 2002). It is a compulsory subject taught from primary up to secondary schools in India.

Students at secondary school level: It is the students learning at secondary school level; the level following upper primary school comprising Standard VIII to X. The present study, it is students studying in Standard IX of Kerala state schools.

Research Questions

The following research questions were addressed in the study.

1. Is CAI in simulation mode effective in enhancing the achievement and motivation in learning Mathematics among secondary school students?

2. Is there any difference in the achievement and motivation in learning of secondary school students taught with CAI-S in Mathematics based on gender?

Research Hypotheses

The hypotheses tested in the study are:

1. There is a significant difference between post-test and pre-test scores of achievement in mathematics among secondary school students taught using CAI-S for the Whole sample and sub-sample based on gender.

2. There is a significant difference between post-test and pre-test scores of motivation in learning mathematics among secondary school students taught using CAI-S for the Whole sample and sub-sample based on gender.

3. There is a significant difference between boys and girls with regard to post-test of achievement in mathematics among secondary school students taught using CAI-S.

4. There is a significant difference boys and girls with regard to post-test of motivation in learning mathematics among secondary school students taught using CAI-S.

Objectives of the study

The research had the following objectives

1. To find if the prepared CAI-S is effective in enhancing the achievement in mathematics of secondary school students taught using CAI-S for the Whole sample and sub-sample based on gender.

2. To find if the prepared CAI-S is effective in enhancing the motivation in learning mathematics of secondary school students taught using CAI-S for the Whole sample and sub-sample based on gender.

3. To find if there is difference in the effectiveness of the prepared CAI-S between boys and girls in enhancing the achievement in mathematics of secondary school students taught using CAI-S.

4. To find if there is difference in the effectiveness of the prepared CAI-S between boys and girls in enhancing the motivation in learning mathematics of secondary school students taught using CAI-S.

2. Research Methodology

Research Design

The study employed a quasi-experimental with a single group pre-test-post-test design. One independent variable, the CAI in simulation mode, was used. Prior to the experimentation, the pupils are pre-tested for their entry-level knowledge. The students in the experimental group are taught the topic circles in Mathematics at Standard IX utilizing a CAI built using simulations. After receiving CAI treatment, students are retested with the same test as the post-test.

Sample

A two-stage sampling technique was used due to the nature of this study. Initially, purposive sampling was employed to choose two secondary schools in the Kollam area of Kerala, India, that followed the Kerala State syllabus. These schools were chosen based on characteristics such as computer labs and internet access. Second, one intact class from each of the two schools is chosen at random as the experimental group. The two schools chosen were based on gender, with one for girls and the other for boys. There are 19 girls and 12 boys in the study's entire sample.

Tools

i.) Treatment Material: The treatment material is a Simulation mode Computer-Assisted Instruction Module (CAIM) for secondary school students to learn Circles in Mathematics. Researchers and a programmer collaborated to create it. It was created as a self-study guide that may be used in a one-on-one context. Microsoft Visual Studio was used as the overarching platform for the CAIM. Geogebra applets, which are publicly available at https://www.geogebra.org/ as classroom materials, were also used during the development process. These are simulations that were created using free open source resources. There were also specific texts, pictures, audio, animations, and movies employed. Computer programmers, educational experts, and school teachers all approved the product (Mathematics). Finally, the product CAI module was pilot tested on three students to eliminate the problems that participants had when utilising the module on their own. The module was divided into twelve lessons and covered subjects linked to the topic circles. The module included an introduction, simulations to learn various topics with remedial methods, a self-check, additional practise problems, and proofs of theorems.

ii. Test Instrument 1: The Mathematics Achievement Test (MAT), devised by the researcher, was employed for collecting data in the present study. The MAT was standardised, and the final instrument had 26 questions: 18 multiple choice questions and 8 short answer questions. The CAIM's contents were used to create the MAT. The experimental groups were given this instrument (PAT) as a pre-test and then again as a post-test after it had been rearranged. For Multiple Choice Questions, a score of '1' given for correct response and a score of '0' for incorrect response was given. A maximum of 3 marks provided for Short Answer Type Questions. As a result, the maximum achievable score for 50 minutes was 42 marks. The test items were validated by ensuring the proper weight-age to content, objectives and form of questions and prepared using blueprint. The reliability coefficient of the test measured by Spearman's split-half method was worked out as 0.93.

iii. Test Instrument 2: Mathematics Motivation Inventory (MMI) prepared and standardised by the investigator consisting of 46 items to measure students motivation in learning mathematics was used in the study. It is a 5-point scale with scores 5 - Strongly Agree (SA), 4 - Agree (A), 3 - Undecided (U), 2 - Disagree (D) and 1 - Strongly Disagree (SD) for positive statements and reversed for negative statements. The Self-Determination Theory of motivation of Edward L. Deci and Richard M. Ryan is the underlying principle used when constructing the tool. The tool was validated by experts in the field of education. The reliability of the MMI was established by Chronbach's Alpha (r = 0.91) which is a measure of inter consistency reliability.

Procedure

The researcher obtained consent from the heads of the schools in question. The subjects were given MAT as a pre-test before the trial began. Following that, students in selected schools participated in a two-week treatment with the cooperation of the staff. The CAIM was hosted on a website and made available over the internet to standalone computer systems and laptops. The computer was used to deliver the mathematics curriculum, and the students learned through interacting with it. The method of Individualized Computer Instruction was applied in this case. Only CAIM was used to teach the students the mathematical principles. On a human-to-computer basis, the computer presented the instruction as self-instructional material.

Data Analysis Procedure

The acquired data were analysed using Statistical Package for Social Sciences to evaluate the hypotheses (SPSS). Differential analysis statistics of Mean and Standard deviation were computed. Paired sample t-test, and Analysis of Covariance (ANCOVA) of post-test scores with pre-test as covariate were the main inferential analysis statistics used.

3. Results

Preliminary Analysis

The descriptive statistics of the Pre-test and Post-test of the experimental group, CAI-S, for Achievement in Mathematics and Motivation in Learning in Mathematics of secondary school students were analysed. The following are the study variables' mean and standard deviation for the overall sample and sub-sample depending on gender.

Table 1

Descriptive statistics mean and standard deviation for Pre-test and Post-test of the students at secondary school level

Variables	Groups	N	Pre-test Scores		Post-test Scores	
			Mean (M_x)	SD (σ_x)	Mean (M_y)	SD (σ_y)
Achievement in Mathematics	Boys	12	8.75	1.77	31.17	3.49
	Girls	19	8.89	2.54	34.79	3.33
	Total	31	8.84	2.24	33.39	3.78
Motivation in Learning Mathematics	Boys	12	149.83	5.44	164.58	7.83
	Girls	19	153.00	13.04	179.63	16.00
	Total	31	151.77	10.74	173.81	15.22

Inferential Analysis

i.) Effectiveness of CAI-S

The effectiveness of the CAI-S treatment utilized in the study was studied by comparing post-test and pretest scores of Achievement in mathematics and Motivation in Learning Mathematics of Secondary School students using a paired t-test for the Whole sample and sub-sample based on gender.

Hypothesis 1: *There is a significant difference between post-test and pretest scores of Achievement in mathematics among secondary school students taught using CAI-S for the Whole sample and sub-sample based on gender.*

The difference of means of post-test and pretest scores of Achievement in mathematics among secondary school students taught using CAI-S for the Whole sample and sub-sample based on gender was analyzed using a paired t-test, shown in Table 2.

Table 2

Paired t-test of Significance of difference between Post-test and Pre-test Scores of the Experimental group for Achievement in Mathematics of students at secondary school level

Variable	Groups	Post-test Mean (M_y)	Post-test SD (σ_y)	Pre-test Mean (M_x)	Pre-test SD (σ_x)	N	df	C.R.	p
Achievement in Mathematics	Boys	31.17	3.49	8.75	1.76	12	11	23.04**	0.00
	Girls	34.79	3.33	8.89	2.54	19	18	30.55**	0.00
	Total	33.39	3.78	8.84	2.24	31	30	34.92**	0.00

*** Significant at 0.01 level*

The paired t-test analysis results on Achievement in Mathematics of the experimental group are given in Table2. Form the calculated $t(30) = 34.92$, $p < 0.00$ for whole sample; $t(11) = 23.04$, $p < 0.00$ for boys and $t(18) = 30.55$, $p < 0.00$ for girls it can be deduced that there is a significant difference between the post-test and pre-test scores at 0.01 level of significance. Achievement in Mathematics for students taught using CAI-S for the Whole sample and sub-sample based on gender. Hence Hypothesis 1 is accepted. It can be deduced that CAI-S is successful in enhancing Achievement in Mathematics for students at the secondary school level for the Whole sample and sub-sample based on gender.

Hypothesis 2: *There is a significant difference between post-test and pretest scores of motivation in learning mathematics among secondary school students taught using CAI-S for the Whole sample and sub-sample based on gender.*

. The difference of means of post-test and pretest scores of motivation in learning mathematics among secondary school students taught using CAI-S for the Whole sample and sub-sample based on gender was analyzed using a paired t-test, shown in Table 3.

. The difference of means of post-test and pre-test scores of motivation in learning mathematics among secondary school students taught using CAI-S for the Whole sample and sub-sample based on gender analysed using a paired t-test, the results of which are shown in Table 3.

Table 3

Paired t-test of Significance of difference between Post-test and Pre-test Scores of the Experimental group for motivation in learning mathematics of students at secondary school level

Variable	Groups	Post-test Mean (M_y)	Post-test SD (σ_y)	Pre-test Mean (M_x)	Pre-test SD (σ_x)	N	df	C.R.	p
Achievement in Mathematics	Boys	164.58	7.83	149.83	5.44	12	11	6.20**	0
	Girls	179.63	16	153	13.04	19	18	15.13**	0
	Total	173.81	15.22	151.77	10.74	31	30	12.60**	0

*** Significant at 0.01 level*

The paired t-test analysis results on motivation in learning mathematics of the experimental group are given in Table2. Form the calculated $t(30) = 12.60$, $p < 0.00$ for whole sample; $t(11) = 6.20$, $p < 0.00$ for boys and $t(18) = 15.13$, $p < 0.00$ for girls it can be deduced that there was a significant difference at 0.01 level of significance between the post-test and pre-test scores. of motivation in learning mathematics for students taught using CAI-S for the Whole sample and sub-sample based on gender. Hence Hypothesis 2 is accepted. It can be judged that CAI-S is beneficial in enhancing motivation in learning mathematics for students at the secondary school level for the Whole sample and sub-sample based on gender.

ii.) Influence of gender

The comparison of boys and girls concerning post-test of Achievement in mathematics and motivation in learning mathematics among secondary school students taught using CAI-S was carried out using Analysis of Covariance with pre-test scores as covariate.

Hypothesis 3: *There is a significant difference between boys and girls with regard to post-test of Achievement in mathematics among secondary school students taught using CAI-S.*

The results of Analysis of Covariance of the post-test scores *of Achievement in Mathematics* with pretest scores as a covariate for boys and girls taught using CAI-S is given in Table 4.

Table 4

ANCOVA for post scores of boys and girls for Achievement in Mathematics with pre-test scores as covariate

Source	Sum of Squares	df	Mean Square	F	p	η_p^2
Contrast	84.08	1	84.08	7.33	0.01	0.21
Error	321.36	28	11.48			
Total	439.36	30				

Table 4 demonstrated that there was no significant difference between boys and girls in the main effect of the treatment F (1, 28) = 7.33, p = 0.01, ηp2 = 0.21. It indicates that the CAI-S had no difference in its effect on students' post-test achievement levels when the covariate effect (pre-test) was controlled. Hence, Hypothesis 3 is rejected. It can be summarised that CAI-S is equally effective in increasing Achievement in Mathematics for boys and girls with regard to post-test when taught using CAI-S.

Hypothesis 4: *There is a significant difference between boys and girls with regard to post-test of motivation in learning mathematics among secondary school students taught using CAI-S.*

The results of the Analysis of Covariance of the post-test scores *motivation in learning mathematics* with pretest scores as a covariate for boys and girls taught using CAI-S is given in Table 5.

Table 5

ANCOVA for post scores of boys and girls for Motivation in Learning Mathematics with pre-test scores as covariate

Source	Sum of Squares	df	Mean Square	F	p	η_p^2
Contrast	1022.46	1	1022.46	15.97	0.00**	0.36
Error	1792.68	28	64.02			
Total	6946.84	30				

*** Significant at 0.01 level*

Table 4 demonstrated no significant difference between boys and girls in the main effect of the treatment F (1, 28) = 15.97, p < 0.00, ηp2 = 0.36 on Motivation in Learning Mathematics. It indicates that the CAI-S significantly affected students' post-test motivation levels when the covariate effect (pre-test) was controlled. Hence Hypothesis 4 is accepted. It can be inferred that CAI-S is not equally effective in escalating Achievement in Mathematics for boys and girls with regard to post-test when taught using CAI-S. From the post-test scores in Table 1, it can be inferred that CAI-S has a more effect on girls than on boys in enhancing their motivation in learning mathematics.

4. Discussion of Findings

The findings revealed that pupils in the experimental group performed significantly better after the intervention CAI-S for the whole sample and sub-sample based on gender. The findings agree with the study of Hillmayr et al., (2020) that using powerful mathematical tools like simulations intelligent tutoring programs was significantly more effective on students Mathematics learning. However, it contradicts the study conducted by Eveline et al., (2019) that the students' conceptual understanding before and after learning is different but not significant enough when using simulations. For the entire sample and sub-sample depending on gender, pupils in the experimental group scored significantly better after the intervention CAI-S for Motivation in learning Mathematics. It is in line with the study of Sari et al., (2019), which found that computer-based laboratory apps were more effective than virtual laboratory applications in enhancing students' motivation. Gambari et al., (2016) reveal that computer simulation to helps their pupils improve students' performance and motivation. In terms of Achievement in mathematics, the results demonstrated no significant difference in performance between boys and girls subjected to CAI-S. The results revealed a substantial difference between boys and girls exposed to CAI-S concerning their motivation in learning mathematics.

5. Implications and Recommendations

It may be deduced from the findings as mentioned earlier that CAI in Simulation mode had a more significant favourable impact on students' learning outcomes and motivation. As a result, they are more effective methods for teaching Mathematics in secondary schools. Computer-supported simulations can give mathematical content in the simplest, most compelling, and exciting ways. It can be incorporated into daily classrooms as supplementary or complementary material for making Mathematics interesting for students. The prepared CAI-S can be a beneficial self-learning module that secondary school teachers can utilize. Teachers should explore more open sources of simulations to teach Mathematics. Girls find computer simulations more motivating than boys, so it can be instrumental to enhance motivation in girls, who usually find Mathematics uninteresting.

Future studies may uncover more topic areas, other content areas, and different levels of learning. Future research should focus on specific categories with a more considerable volume of participants across various demographics, measuring a broader range of variables, and using CAI in various situations or in conjunction with other instructional methodologies.

6. Limitations of the study

The study had its limitations of being conducted on a small sample. The experimental study was conducted for a short duration of time. Also, other dimensions of Achievement like lower and higher-order objectives and Motivation like Intrinsic and Extrinsic motivation were not considered.

7. Conclusion

In terms of technology, our environment is constantly changing. In the current state of our classrooms, integrating technology with various media and applications is quite simple. The usage of CAI-S simulation-based software aids students in manipulating data and makes mathematics more fun to study. It can integrate technology into the classroom as part of a blended formal program and as a standalone program. Students will undoubtedly benefit from such technologies in terms of Achievement and motivation in learning, particularly in a challenging subject like mathematics.

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