USE OF MICROCOMPUTER SIMULATIONS TO OVERCOME STUDENT MISCONCEPTIONS ABOUT DISPLACEMENT OF LIQUIDS

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Abstract

This study compared the effectiveness of computer simulated experiments with that of parallel instruction involving hands-on laboratory experiments for teaching volume displacement concepts. The purpose of the simulation was to have students test their misconceptions rather than simply being told about erroneous misconceptions. This study also assessed the differential effect of students' understanding of the volume displacement concepts in the cognitive category of knowledge and application. In addition, it compared the degree of retention, after 30 days, of both treatment groups. 389 students from 6 Malaysian schools participated in the study. The results indicated that there were significant differences between the two groups in terms of learning gains in the cognitive category of knowledge as well as in the cognitive category of application. The implications of these results for the design of computer-based instruction for the teaching of science are discussed.

Introduction

The purpose of this research was to test the effectiveness of computer simulations for teaching displacement concepts. Students learning science may already have acquired misconceptions (also called "preconceptions" or "alternative frameworks") that may be an obstacle to their learning (Driver & Easley, 1978; Ausubel, Navok, & Hanesian, 1978). Such misconceptions have been reported in many areas of science (Champagne, Gunstone, & Klopfer, 1985) including displacement of liquids (Rodrigues, 1980, Linn and Pulos, 1983). In the area of displacement of liquids Linn and Pulos demonstrated a developmental sequence of misconceptions relating to 1) the relationship between the volume of an object to the volume of water displaced; 2) the relationship between the shape of the object and the volume of water displaced; 3) the relationship between the mass of an object and the volume of the water displaced; 4) the relationship between the size of an object and the volume of water displaced; and 5) the relationship between different types of liquids and the volume of each liquid displaced by an object.

Purpose

The study was to determine if computer simulated experiments (CSE) enhanced student learning more significantly than hands-on laboratory experiments (HOL) in the studying of concepts related to displacement of liquids. Using an experimental control group design, subjects were given a Cattell Culture Fair Test, a pretest and two posttests (one immediately after the treatment and the other 30 days after the treatment). The dependent variables were initial student learning in the cognitive category of knowledge, initial student learning in the cognitive category of application, retention of learning in the cognitive category of knowledge and retention of learning in the cognitive category of application. The independent variables were treatment and sex. Specifically, this study sought to answer the following questions:

1. Are there significant differences in learning gains in the cognitive category of knowledge between the computer simulated experiment (CSE) learners and hands-on laboratory (HOL) learners?

2. Are there significant differences in learning gains in the cognitive category of application between the computer simulated experiment (CSE) learners and hands-on laboratory (HOL) learners?

3. Are there gender differences in the learning of volume displacement concepts?

4. Will students who are taught the volume displacement concepts using computer simulated experiments retain as much knowledge of volume displacement in the cognitive category of knowledge and application as students who are taught this concept using hands-on laboratory experiments?

Subjects

The participants were 389 students from six Malaysian schools comprising of 191 male and 198 female volunteers who had not been taught this topic

before. The students ranged in age from 12.83 to 13.51 years old with a mean age of 13.04 years old and a standard deviation of 0.40 years. In selecting subjects of this study, the average age of the subjects was taken into account. Research findings have reported that volume displacement concept is not formed in the students before 12 years of age (Phillips, 1971). All subjects in this study had experiences with computers in their mathematics and science classes.

Materials

Computer Simulation Experiments

The theoretical paradigm used in the design of the simulation is based on the Events of Instruction by GagnÇ and Briggs (1979). The nine sets of instructional external events are arranged so as to ensure that the desired learning process takes place internally. Actual design guidelines of the simulation were based on suggestions from Jonassen & Hanun (1987) and Alessi & Trollip (1985) who gave detailed prescriptions on how to design the four main components of a simulation - namely the scenario, learner response, feedback and lesson control. Furthermore, prescriptions from Charles M. Reigeluth and Ellen Schwartz (1989) for designing the instructional overlay to optimize learning and motivation were incorporated into the simulation. The simulation was designed by the researcher using Turbo C, (Version 2) as the programming language. The graphic and animation screens were designed using IBM P.C Storyboard Plus and later linked to the Turbo C compiler. To conserve diskette space taken by the graphic images, a routine was developed to compress the graphic images from 16 Kilobytes to 3 kilobytes and stored; then subsequently decompressed and read when required. The systematic development of the simulation from the conceptualization stage till the finished product was based on the Instructional Systems Development Model (O'Neil, 1979; Dick and Cary, 1985; Gagnä and Briggs, 1989).

There were six simulations. A typical simulation was presented in the following manner:(Fig. 2 - 10). The summary of all the six simulations was given in Fig. 11 Events of Instructions:

1. Gaining attention

2. Informing learner of lesson objectives

    Procedure:

    1. Present an graphic screen with animation and sound to attraction students' attention. See Fig. 2

    2. Display of menu screen that showed summary of concepts. See Fig. 3

    3. Simulating recall or prior learning

    4. Presenting scenario

3. Display bullet text that is accompanied with sound to assist student recall, i.e. explain purpose of simulation. See Fig 4

4. Simulating two objects A and B that have the same volume but different masses being dropped into the eureka can separately. Using direction keys (up or down), user can choose the object to put into the can. See Fig. 5

5. Guiding learning

6. Eliciting performance

5. Simulating water flowing out of the eureka can and being measured using a measuring cylinder. The volume of water displaced depends on the volume of the object, not its mass. See Fig. 6

6. After user has chosen the object he wants, he has to press <ENTER> key. If the wrong key is pressed a "pop-up" message is displayed accompanied by a warning sound. See Fig. 7

7. Providing informative feedback

8. Assessing performance

7. Displaying a graphic screen line by line followed by sound to give the user a summary of the concept that they have just learnt. See Fig. 8

8. Giving a quiz to assess user's understanding of the concept. See Fig. 9

9. Enhancing retention and learning transfer

9. Using the branching technique, if the learner could not give the correct response after two trials, he will be guided to the simulation again. See Fig. 10

Fig. 11
Summary of the Computer Simulated Experiments

Procedure

An experimental design using a control group known as "The Pretest Posttest Control Group - Design 2 " (Isaac, 1981; Campbell and Stanley, 1963) was used in this study. The dependent variables were gain in scores between the pretest and posttest and the retention test scores. The independent variables were treatment, cognitive category in the test and gender of students. Students in each class were randomly assigned to one of two treatment groups, the microcomputer-simulated experiment group (the experimental group) and the hands-on laboratory experiment group (the control group). The experimental group consisted of 97 male and 91 female students. The control group consisted of 94 male and 107 female students. The experimental and control groups of students were both taught the following volume displacement concepts.

1. An object when submerged in a liquid will displace the volume of the object, not its mass.

2. The volume of the liquid displaced by a submerged object is equal to the volume of the object.

3. Two floating object that have the same mass, but different volume, will displace the same volume of liquid.

4. Submerged objects, when broken into smaller pieces, will displace the same volume of liquid.

5. Changing the shape of a submerged object does not change the volume of the liquid displaced.

6. Objects submerged in liquid displace their volumes,

irrespective of the type of liquids used.

The experimental groups were taught these six concepts using a series of six simulated experiments on the IBM PC microcomputer. The control groups were taught these concepts using six parallel hands-on laboratory experiments designed by the researcher with the assistance of several science teachers.

The Experimental Group

The computer software which was used by the experimental group included six simulated experiments and took about 20 minutes to complete. Included in the software were six simulated experiments with the concepts mentioned. The peer tutoring and learning approach (Lourdusamy, 1988) was used in the conduct of the simulation. In this method, a computer is shared by three students. Each of the student took turns to become the group leader in each simulation.

The Control Group

The instructional materials for the hands-on laboratory experiment group (the control group) were designed by the researcher with the assistance of five subject specialists. They consisted of six experiments for understanding volume displacement concepts. The experiments were parallel to those used in the microcomputer simulated experiments. The conduct of these experiments took almost two full periods (80 minutes in all).

Instruments

There were four instruments in this study. They included the Cattell Culture Fair Intelligence test and the Physics Achievement test which was subdivided into the pretest, posttest and retention test. The Physics achievement test consisted of a twenty four multiple choice questions which were developed to determine student understanding of important concepts related to volume displacement. An item analysis was carried out on the results of the testing and employed three types of information - item difficulties, discrimination indices, and the pattern of responses to the various distracters - to improve the test.   Content validity of the twenty item test was established by the five science specialists who designed the instrument. Reliability of the test was estimated to be using the Cronbach Alfa procedure. The Cronbach Alfa coefficient was 0.89 showing that the test instrument was satisfactorily reliable. The Cattell Culture Fair Intelligence test was administered to all the students in this study to see whether randomness was achievement in the assignment of the subjects to the two groups in terms of intelligence.

A pretest was administered before the treatment to both groups. Immediately after the treatment, a posttest was administered to the students. A retention test was administered to the students 30 days later. A two-way analysis of variance was used for analysing the data.

Results

Posttest

The questions asked in the study were put in the form of a series of null hypotheses. The first question was: There will be no significant differences in the cognitive category of knowledge between the performance of students in the computer simulated experiment and that of students in the hands-on laboratory groups as measured by the gain scores between the posttest and the pretest. Results of data analysis rejected the null hypothesis. The gain score for the computer simulated experiment group was higher (9.622 - 6.637 = 3.255) compared to the hands on laboratory group (8.816 - 6.154 = 2.662) (TABLE I). An ANCOVA analysis (TABLE II) revealed that the gain score between the computer simulated experiment group and the hands-on laboratory group was significant, (F, (1, 384) = 11.969, $p < 0.05$). Students in the CSE groups benefit more when learning the volume displacement concepts.

TABLE I

Means and Standard Deviations for Achievement Tests for two Treatment Groups in the Category of Recall

Variables	Achievement tests		
	Pretest	Postest	Retention Test
Computer-Simulation Group	6.367 (1.959) N=188	9.622 (1.962) N=188	8.399 (2.178) N = 188
Hands-on laboratory Group	6.154 (1.800) N = 201	8.816 (1.908) N = 201	7.602 (2.067) N= 201

TABLE II

ANALYSIS OF COVARIANCE OF GAIN SCORE IN THE COGNITIVE CATEGORY OF KNOWLEDGE (POSSTEST SCORE MINUS PRETEST SCORE) FOR EACH SEX IN EACH TREATMENT GROUP (USING THE CATTELL CULTURE FAIR INTELLIGENCE TEST AS A COVARIATE)

* * A N A L I S Y S I S O F C O V A R I A N C E * *

Source of Variation	Sum of square	DF	Mean square	F	Significance of F
Covariate	26.125	1	26.125	8.357	.004
INTELLIGENCE	26.125	1	26.125	8.357	.004
Main effect	74.615	2	37.307	11.933	.000
GROUP	37.419	1	37.419	11.969	.001
SEX	40.837	1	40.837	13.062	.000
2-Way					

Interaction	13.723	1	13.723	4.389	.037
GROUP X SEX	13.723	1	13.723	4.389	.037
Explained	114.463	4	28.616	9.153	.000
Residual	1200.509	384	3.126		
TOTAL	1314.972	388	3.389		

The second question in the study was formulated as the following null hypothesis: There will be no significant differences between the performance in the cognitive category of application between the CSE group and the HOL group as measured by the gain score between the pretest and the posttest. Results of the data analysis (TABLE IV) showed a significant main effect by treatment group, ($F (1, 384) = 13.72$, $p < 0.05$ and hence the null hypothesis was rejected. Students learning through the computer simulated experiments showed higher achievement in the cognitive category of application compared to those of the hands on laboratory group (TABLE III).

TABLE III

MEANS AND STANDARD DEVIATIONS FOR ACHIEVEMENT TEST SCORES IN EACH TREATMENT GROUP IN THE CATEGORY OF APPLICATION

Variable	Achievement Test score		
	Pretest	Post Test	Retention Test
Computer	5.484	7.947	7.239
Simulation	(1.972)	(1.997)	(2.110)
Group	N=188	N=188	N=188
Practical	5.507	7.398	6.701
"Hands-on"	(1.908)	(1.934)	(2.086)
Group	N = 201	N = 201	N= 201

TABLE IV

ANALYSIS OF COVARIANCE OF GAIN SCORE IN THE COGNITIVE CATEGORY OF APPLICATION (POSSTEST SCORE MINUS PRETEST SCORE) FOR EACH SEX IN EACH TREATMENT GROUP (USING THE CATTELL CULTURE FAIR INTELLIGENCE TEST AS A COVARIATE)

* * A N A L I S Y S I S   O F   C O V A R I A N C E * *

Source of	Sum of	DF	Mean	F	Significance of

Variation	square		square		F
Covariate	6.702	1	6.702	2.731	.099
INTELLIGENCE	6.702	1	6.702	2.731	.099
Main Effect	37.069	2	18.534	7.554	.001
GROUP	32.808	1	32.808	13.372	.000
SEX	5.483	1	5.483	2.235	.136
2-Way interaction	26.211	1	26.211	10.683	.001
GROUP X SEX	26.211	1	26.211	10.683	.001
Explained	69.982	4	17.495	7.131	.000
Residual	942.157	384	2.454		
Total	1012.139	388	2.609		

Gender differences

The third question in the study was formulated in the following null hypothesis: There will be no significant difference in learning gains in the cognitive category of knowledge between the performance of males and that of females in each treatment group. Table V showed that females showed higher overall gain score compared to males (3.268 vs 2.618). The gain scores for the females were higher in both the CSE group (3.823) as well as in the HOL group (2.794). A two-way ANCOVA of the gain scores (Table II) revealed that females scored significantly higher than males (F (1, 384) = 13.062, p ,0.05). Hence the hypothesis was rejected. The fourth question in the study was formulated in the following null hypothesis: There will be no significant difference in learning gains in the cognitive category of application between the performance of males and that of females in each treatment group. Table VI showed that females showed higher overall gain score compared to males (2.278 vs 2.053). The gain scores for the females were higher in both the CSE group (2.879) but in the HOL group, males had higher gain scores(2.032). A two-way ANCOVA of the gain scores (Table IV) revealed that the gain scores amongst males and females in the cognitive category of application had not reached the 0.05 level of significance. Results of data analysis did not reject the null hypothesis.

TABLE V

ANALYSIS OF GAIN SCORE IN THE COGNITIVE CATEGORY OF KNOWLEDGE BETWEEN THE PRETEST AND POSTTEST FOR 389 STUDENTS IN EACH TREATMENT GROUP FOR EACH SEX

Treatment Group	N	Pretest	Posttest	Mean gain score
		MALES AND FEMALES COMBINED		

CSE	188	6.367	9.622	3.255
HOL	201	6.154	8.816	2.662
MALES				
CSE	97	6.329	9.051	2.722
HOL	94	6.010	8.521	2.511
FEMALES				
CSE	91	6.407	10.230	3.823
HOL	107	6.280	9.074	2.794
Total				
MALES	191	6.172	8.790	2.618
FEMALES	198	6.338	9.606	3.268

CSE = Computer simulated experiment; HOL = Hands on Laboratory

Retention Test

The fifth question in the study that the retention test administered 30 days after the posttest, was designed to measure was formulated as the following null hypothesis: There will be no significant differences in retention in the cognitive category of knowledge between the performance of students in the computer-simulated experiment group and that of students in the hands-on laboratory groups as measured by a retention test.

TABLE VI

ANALYSIS OF GAIN SCORE IN THE COGNITIVE CATEGORY OF APPLICATION
BETWEEN THE PRETEST AND POSTTEST FOR 389 STUDENTS IN EACH TREATMENT GROUP FOR EACH SEX

Treatment Group	N	Prettest	Posttest	Mean gain score
Males and Females combined				
CSE	188	5.484	7.946	2.462
HOL	201	5.507	7.398	1.890

Males				
CSE	97	5.082	7.154	2.072
HOL	94	5.170	7.202	2.032
Females				
CSE	91	5.912	8.791	2.879
HOL	107	5.803	7.570	1.767
Total				
Males	191	5.125	7.178	2.053
Females	198	5.853	8.131	2.278

CSE = Computer simulated experiment; HOL = Hands-on Laboratory

Table VII showed that the mean score of the CSE group was higher (8.3989) compared to the HOL group (7.6020). An ANCOVA of the retention test for the cognitive category of knowledge (Table VIII) showed a significant main effect by treatment, $F(1, 384) = 18.726$, $p < 0.05$. This indicated that students showed higher retention of what they learnt in the cognitive category of knowledge by learning through computer simulated experiments compared to those of the hands-on experiments group.

TABLE VII
MEANS AND STANDARD DEVIATIONS OF THE RETENTION TEST SCORES IN THE COGNITIVE CATEGORY OF KNOWLEDGE FOR 389 STUDENTS IN EACH SEX FOR EACH TREATMENT GROUP

VARIABLE	MEAN	STD DEVIATION	NO. OF STUDENTS
FOR WHOLE POPULATION	7.9871	2.1556	389
MALES	7.6545	2.2794	191
FEMALES	8.3081	1.9824	198
CSE GROUP	8.3989	2.1780	188
MALES	7.7938	2.3802	97
FEMALES	9.0440	1.7315	91
HOL GROUP	7.6020	2.0666	201
MALES	7.5106	2.1739	94
FEMALES	7.6822	1.9744	107

TABLE VIII

ANALYSIS OF COVARIANCE OF THE RETENTION TEST SCORES IN THE COGNITIVE CATEGORY OF KNOWLEDGE FOR 389 STUDENTS FOR EACH SEX IN EACH TREATMENT GROUP USING CATTELL "CULTURE FAIR" INTELLIGENCE TEST AS A COVARIATE

* * * A N A L Y S I S O F C O V A R I A N C E * * *

Source of Variation	Sum of square	DF	Mean square	F	Significance of F
Covariate	395.572	1	395.572	116.717	.000
Intelligence	395.572	1	395.572	116.717	.000
Main					
Effect	90.571	2	45.285	13.362	.000
GROUP	63.466	1	63.466	18.726	.000
SEX	31.239	1	31.239	9.217	.003
2-WAY					
Interaction	15.359	1	15.359	4.532	.034
GROUP X SEX	15.359	1	15.359	4.532	.034
Explained	501.501	4	125.375	36.993	.000
Residual	1301.434	384	3.389		
Total	1802.936	388	4.647		

The final question in the study was formulated as the following null hypothesis: There will be no significant differences in retention in the cognitive category of application between the performance of students in the computer-simulated experiment group and that of students in the hands-on laboratory groups as measured by a retention test.

Table IX showed that the mean score of the CSE group was higher (7.9468) compared to the HOL group (7.3980). An ANCOVA of the retention test for the cognitive category of application (Table X) showed a significant main effect by treatment, $F(1, 384) = 8.861$, $p < 0.05$. Thus the null hypothesis was rejected. This indicated that students in the CSE group showed a higher retention of what they learnt in the cognitive category of application compared to those from the HOL group.

TABLE IX

MEANS AND STANDARD DEVIATIONS FOR THE RETENTION TEST SCORES IN EACH TREATMENT GROUP FOR EACH SEX FOR 389 STUDENTS

VARIABLE	MEAN	STANDARD DEVIATION	STUDENTS
FOR WHOLE POPULATION	7.6632	1.9812	389
MALES	7.1780	2.0647	191

FEMALES	8.1313	1.7806	198
CSE GROUP	7.9468	1.9966	188
MALES	6.4948	2.1219	97
FEMALES	8.0330	1.7917	91
HOL GROUP	7.3980	1.9341	201
MALES	6.5106	2.2754	94
FEMALES	6.8692	1.8988	107

TABLE X
ANALYSIS OF COVARIANCE OF THE RETENTION TEST SCORES IN THE COGNITIVE CATEGORY OF APPLICATION FOR 389 STUDENTS FOR EACH SEX IN EACH TREATMENT GROUP USING CATTELL "CULTURE FAIR" INTELLIGENCE TEST AS A COVARIATE

* * A N A L Y S I S O F C O V A R I A N C E * *

Source of Variation	Sum of square	DF	Mean square	F	Significance of F
Covariate	273.258	1	273.258	78.160	.000
Intelligence	273.258	1	273.258	78.160	.000
Main Effect	92.845	2	46.422	13.278	.000
GROUP	30.978	1	30.978	8.861	.003
SEX	66.066	1	66.066	18.897	.000
2-Way Interactions	21.808	1	21.808	6.238	.013
GROUP X SEX	21.808	1	21.808	6.238	.013
Explained	387.911	4	96.978	27.739	.000
Residual	342.511	384	3.496		
Total	1730.422	388	4.460		

Discussion

The finding in this study that the performance of the students in the computer simulated group had higher achievement compared to the hands-on laboratory group in the learning of volume displacement concepts supported studies done by other researchers such as Choi, B. S. & Gennaro, E. (1987), Jones (1972) and Cavin and Lugowski (1978) who showed that computer simulated experiments were as effective as hands-on laboratory experiments in concept learning. Hence the teaching of concepts in science using computer simulations could be a viable alternative in lieu of hands-on laboratory experiments.

The finding in this study that the retention score of students in the computer simulated group had higher that those in the hands-on laboratory group supported research conducted by Edwards, et al., (1975), Thomas (1979) and Kulik, et al., (1975). Their researchs revealed that the

retention of students learning through CAI was higher than the non-CAI group. This could be due to the attributes of computer having the ability to give immediate feedback. Research by Thyne (1963) showed that media that gave immediate feedback would increase retention in learning.

This study also showed that there were differences in achievement between males and females; i.e. females seemed to score higher than males in the cognitive cagetory of knowledge. This finding could be spurious and inconclusive. Up till now there is no concrete findings that suggested that there are gender differences in cognitive achievement. Maccoby & Jacklin (1974), concluded that gender differences existed for (a) verbal ability, (b) quantitative ability, and (c) spatial ability. But a meta analysis conducted by Linn & Hyde (1989) on gender differences in cognitive achievement revealed that gender differences in these areas have declined and not uniform within these categories. Ruel (1990) suggested that gender differences in achievement could be due to maturation, which favours girls over boys, cultural and sex-role expectations that precipitated differing student performances.

Implications of the Study

One of the implications of this study is that a computer-simulated experiment can be used in place of a hands-on laboratory experience. Achievement of students using this mode is comparable to that of hands-on laboratory experience. In the Malaysian scenario, an ambitious project is currently on the pipe line where eventually all secondary schools (1,407 of them) will be equipped with microcomputers (Khoo, 1990). Hence the use of computer simulations to teach concepts in science seem to be a good alternative.

Another implication of this study is that computer-simulations could be used for students who missed their science practical class. Computer-simulations could be also a good substitute for expensive and dangerous experiments.

Yet another implication of this study is that concept learning through computer-simulations speeds up the learning time. Students learning through the CSE achieve an equal performance level in approximately one fourth the time required for the hands-on laboratory experiments. (20 minutes versus 80 minutes).

Limitations of study

The first limitation of this study is novelty effects experienced by students learning using high-technology instructions because these media may seem to be of interest to students simply due to their being perceived as new or especially modern. How large an influence novelty effects have on the data is difficult to determine, if not impossible to tell. The second limitation is that students in the CSE group were exposed to computer-simulations for only 25 minutes. It would be more appropriate if the study could be further extended so that students could be exposed to more computer-simulations and their achievement measured over a long period of time. The third limitation of this study is that students involved in this study were from six secondary schools in the state of Penang and might not be representative for the whole nation of Malaysia. Lastly, this study is limited by the quality of the computer-simulation software and the hands-on practical worksheets devised by the researcher.

Suggestions for future research

Several questions, issues and observations raised by this study should be considered in planning other research in this area:

1. Is there a correlation between the psychological constructs of students (such as their cognitive style, self-concepts and creativity) and achievement of students learning through computer-simulations?

2. Will the same study yield the same result if extended to other topics in science?

3. Will the achievement of students increase if CSE is used as an adjunct to hands-on practical experience?

4. What are the attributes of a computer screen layout in a computer simulation that motivates the user?

Conclusions

Because of the demonstrated value of computer simulations, it is important that learners be given the opportunity to use them early in their experience with displacement of liquids. Volume displacement concepts are important science concepts which are necessary for the understanding of other concepts such as density, Archimedes Principle and Floatation Laws (Gennaro, 1966, Blake, Lawson, & Nordland, 1974; Gennaro, 1981; Linn & Pulos, 1983). With the advent of the rapid proliferation of faster and cheaper computers and multimedia into the classroom, the efficacy of using simulations would be even pronounced.

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