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Effectiveness of Understanding by Design and Computer-Aided Instruction in Learning Mathematics II

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ABSTRACT

The academic achievements of students in Mathematics greatly depend on the effectiveness of teaching methodologies employed in the classroom. Thus, it is the task of mathematics teachers to evaluate persistently the teaching and learning process in mathematics subjects as part of curriculum development and students' evaluation process. The experimental-descriptive design was used to compare the effectiveness of Understanding by Design (UBD) and Computer-Aided Instruction (CAI) on students' test scores and determinants of learning which includes motivation, concept formation, application and retention, in learning special products and factoring. The respondents composed of 50 second-year high school students from Zambales National High School and Botolan National High School. A pretest and a posttest were administered before and after the instruction using UBD and CAI, respectively, to measure the student performance. A Likert-type perception instrument was used to assess the effectiveness of UBD and CAI on the particular learning aspects. The values for the pretest and posttest mean, median and modal scores were significantly higher for CAI than for UBD. There is moderately low positive correlation between the students' performance and perception under UBD instruction and very low positive correlation under CAI instruction. It is recommended that the CAI-based learning method be used to supplement UBD-based instruction to provide students with frequent, immediate and adequate feedback in the traditional classroom practice.

Keywords — Mathematics Education, Computer-Aided Instruction, learning, experimental-descriptive design, Philippines

INTRODUCTION

The benefits of teaching for understanding in optimizing academic performance have been documented in industrialized countries like United States of America, Japan and Germany (Martin, Mullis, Gregory, Hoyle & Shen, 2000). The data from the Third International Mathematics and Science Study (TIMSS) test showed that although the Japanese teach fewer topics in Mathematics, their students achieved better results. The primary aim of Japanese teachers is to develop conceptual understanding in their students. Emphasis is given on problem-based learning in which rules and theorems are derived and explained by students, leading to deeper understanding (Stigler & Hiebert, 1999). However, the framework and standard for basic education, in general, and for basic mathematics education, in particular, depend on the prescribed curriculum. Curriculum includes the materials used for learning. It also refers to the course of study for each discipline and the scope and sequence within each grade level to build conceptual understanding (Mastropieri & Scruggs, 2000).

In the Philippines, the secondary education curriculum underwent a series of revisions and innovations from the Basic Education Curriculum to Revised Basic Education Curriculum until the introduction of Understanding by Design in June 2010. The Understanding by Design framework was implemented in the Philippines following its success in the United States of America. Its implementation in June 2010 was mandated by the Department of Education Order Number 76 Series of 2010 so that the level of performance and achievement in learning of students is attained through the application of the concept of teaching for understanding rather than using the traditional method of focusing on facts with the expectation that understanding follows. The benefits of understanding by design in optimizing student performance and achievement in learning Mathematics II is given emphasis in this study. Achievement in mathematics is essential in attaining success in school and in life. Mathematics is the academic discipline concerned with the solution of problems that involve quantity or number. It focuses on the thematic process that includes problem solving, reasoning, communicating and connecting. Its application transcends across many academic disciplines and fields of endeavor. In the secondary level, the focus of Mathematics is the study and enrichment of Algebra (Quan & Tan, 2009). Algebra is an important branch of Mathematics which is required for more advance problem solving in the field of business and industry. Algebra is abstract in nature that involves the use of letters x and y to represent unknown quantities in the solution of problems.

The National Achievement Tests (NAT) conducted yearly by the National Education, Training and Research Council (NETRC) showed that the achievement rate for the elementary or Grade 6 level has improved from 55% in SY 2006-2007 to 66% in SY 2009-2010 in all the subject areas. However, it remains below the minimum of at least 75%. Second year students fared worse as their NAT scores remained virtually unchanged during the said period especially in Mathematics and Science (Senate Economic Planning Office, 2010).

Traditionally, teaching Mathematics considers the teachers as source of all concepts, and the students are merely passive learners. As a result, instead of gaining a deep understanding, students who are exposed to the traditional method of teaching and learning tend to be less productive in terms of conceptualizing the nature of Mathematics. In contrast to the traditional method of teaching and learning, the principles underlying Understanding by Design as defined by the Southern Regional Education Board (1992) include a challenging curriculum that equip students to think analytically, to reason, to judge and to balance opposing points of view. The UBD framework encourages students to use knowledge to solve problems, to use academic and technical content and processes to complete tasks typical of those found in the workplace and in the community, and to construct new meanings and understanding from information and ideas. It was revealed that teachers recognize students' behavior in response to the UBD framework. Students tend to engage in active construction of meaning rather than mere memorization, achieve sense of fulfillment in arriving at the ideas, and anticipate variety of instructional activities (Lim & Prudente, 2013). UBD helps educators not only to increase learning outcomes but also elevate students' motivation (Brown, 2004; Childre, Sands & Pope, 2009). In terms of cultural/regional context, UBD has been successfully used in many schools across the United States and Canada (Brown, 2004).

The study also focused on the use of modern technology parallel to UBD as an alternative learning method. Previous studies by Kissane and Kemp (2008) showed that a graphics calculator affected teaching and learning of calculus. The GeoGebra (Kissane, 2009) is an example of computer software that uses the idea of dynamic geometry in the area of statistics. Considered one of the important driving forces on curriculum change, computer- aided instruction (CAI) in Algebra, particularly, on the topics on special products and factoring was developed. Special product is a topic that refers to the process of expansion of a given polynomial. Factoring refers to the process of expressing a number as the product of its factors. The CAI is an interactive instructional technique where a computer is used to present the instructional material and monitor the learning that takes place. Using a combination of text, graphics, sound and video, CAI can be used either in isolation, bearing the whole responsibility for conveying instruction to students, or in combination with conventional face-to-face teaching methods.

The study was undertaken to compare the effectiveness of UBD and CAI in learning Mathematics II in terms of pretest and posttest scores in special products and factoring and in terms of perception on motivation, concept formation, application and retention.

OBJECTIVES OF THE STUDY

The study aimed to compare the effectiveness of understanding by design and computer aided instruction in learning Mathematics II in Zambales National High School and Botolan National High school during the school year 2012-2013. Specifically, the study identified how was the student's performance in the pretest and posttest in special products and factoring using UBD and CAI described in terms of mean, median, and mode; how do the respondents perceive the effectiveness of UBD curriculum and CAI in learning Mathematics II in terms of motivation, concept formation, application and retention.

METHODOLOGY

Research Design

The experimental-descriptive design was used to measure and compare the effectiveness of UBD and CAI based on the test scores in Mathematics II and perception of the students. The pretest-posttest experimental research design was used where the total population of participants was randomly divided into two groups-the control group and the experimental group. Only the experimental group was exposed to the manipulated variable, CAI. The control group undertook the usual UBD-based instruction. The descriptive design was used to determine the perception of the respondents on the effectiveness of UBD and CAI in learning Mathematics II. The lessons in Mathematics II focused on special products and factoring.

Participants and Research Site

The respondents consisted of second year students of the Zambales National High School (ZNHS) and Botolan National High School (BNHS) officially enrolled during the school year 2012-2013. Purposive sampling was utilized taking both the first section of the second-year level students. The respondents in the control group were exposed to UBD learning. The same lessons were undertaken by the experimental group through computer-aided instruction. There were 50 students each from ZNHS and BNHS. The group of 50 students from each school was divided into two groups of 25 students each. The two groups of 25 students each from ZNHS and BNHS respectively were taught using UBD. The other two groups of 25 students each were taught using CAI.

Instrumentation

The data-gathering process consisted of the experimental component and the descriptive component. For the experimental component, the instruments used were the CAI software and the UBD-based instruction on special products and factoring. All respondents took the pretest and posttest.

For the descriptive component, the survey questions were used as instrument to determine the perception of the respondents on the effectiveness of the UBD-based and CAI instruction.

The researcher sought the advice of the thesis adviser, information technology (IT) experts and Mathematics teachers handling UBD-based classes on the construction and validation of the instrument. A draft of the questionnaire was prepared following the guidelines given by the faculty of the graduate school.

The pretest and posttest were prepared using test items selected from the 2011 First Periodic Test and 2012 Division Achievement Test of the Department of Education. Additional test items were patterned from the standardized examinations from UBD-based curriculum given by the Department of Education during the last few years. A copy of the test items, the questionnaire and overview of the study was submitted to the Office of the Division Schools Superintendent.

The CAI software was developed based on the topic for instruction - special products and factoring. The CAI and UBD-based instruction were similar in terms of concepts, objectives and coverage but were different in the presentation of the lesson.

To test the validity, the researcher conducted a pilot-testing of the instruments to all the second year students of Rofulo M. Landa High School (Palauig, Zambales). The CAI software was tested with the similar level of students from private school nearby. During the pilot testing, the researcher noted observations on the comprehension of survey questions by students, test items, allocation of time for the test, and allocation of time to run the CAI software.

Data Collection

Prior to the administration of pretest, the researcher conducted a brief discussion regarding the study. The objectives, methods, and implications of the conduct of the study were clearly presented to the respondents. Queries and questions have been raised and answered. Lastly, informed consent forms were accomplished by the respondents.

A pretest was given to all the respondents from Zambales National High School and Botolan National High School before the start of the lesson on special products and factoring. The pretest was administered during the first week of classes of the school year 2012-2013. The respondents from ZNHS and BNHS were equally divided into two groups comprising of the control group who attended the UBD-based class and the experimental group who attended the CAI-based class.

The CAI-based class was done from two to three hours for three consecutive days. After the completion of the UBD-based and CAI-based lesson on the two separate groups, the posttest was administered to all the respondents. All respondents were also required to answer the survey questionnaire. The respondents in the experimental group were required to write observation about the CAI-based learning experience. The information, data and test results collected were tallied, tabulated and analyzed using appropriate statistical tools.

Statistical Techniques

The study utilized statistical techniques such as the measures of central tendency (mean, median, mode), weighted mean, Likert scale, standard deviation, measures of skewness, person-r correlational test, t-test and F-test (single-factor ANOVA).

RESULTS AND DISCUSSION

Students' Pretest and Posttest Scores in UBD and CAI

The mean, median and modal scores in special products and factoring using UBD and CAI are presented in Table 1.

Table 1 . Pretest and Posttest Mean, Median and Modal Scores and Skewness using UBD and CAI

Statistics	Pretest		Posttest	
	UBD	CAI	UBD	CAI
Mean	7.94	10.76	10.46	14.80
Median	8.00	10.00	10.00	15.00
Mode	8.00	9.00	5.00	11.00
Skewness	0.78	0.18	0.24	0.24

The pretest and posttest mean, median and modal scores were higher when the lessons on special products and factoring were taught and learned using CAI than when the instruction was UBD-based (Table 1). More students obtained low scores than high scores during the pretest and posttest for UBD and CAI. It was reported in the study by Mann (1999) that use of computer application was more effective than the traditional method of teaching mathematics among fifth-grade students. Some of the instructional benefits that the use of computer software provides are better retention and more positive attitude (Cotton, 2001). Others studies showed that the use of educational technology in teaching and learning may, among other things, help pupils in putting greater focus in understanding the more difficult and complex concepts (Doerr & Zangor, 2000) as well as help them develop a conceptual understanding of such concepts (Kaput, Hegedus & Lesh, 2007; Kebritch, Hirumi & Bai, 2010).

Effectiveness of UBD and CAI as Perceived by the Students

The data on the overall weighted mean on perception on the effectiveness of UBD and CAI on the aspects of motivation, concept formation, application and retention is presented in Table 2 and Table 3.

Table 2. Summary on the Perception of the Effectiveness of UBD on the aspects of Motivation, Concept Formation, Application and Retention in Learning Special Products and Factoring

Learning Aspects	Overall Weighted Mean	Descriptive Rating	Rank
Motivation	3.81	Very Effective	3.5
Concept Formation	4.07	Very Effective	1
Application	3.87	Very Effective	2
Retention	3.81	Very Effective	3.5
Grand Mean	3.89	Very Effective	

The Understanding by Design was perceived to be very effective in learning special products and factoring on the aspect of concept formation which ranked first with an overall weighted mean of 4.07. The aspect of application was second in rank. Motivation and retention ranked 3.5th (Table 2). The UBD was perceived to be very effective with grand mean of 3.89. Experts in Physics, Mathematics and History who developed understanding of problems in terms of core concepts, found its effectiveness in concept retention (National Research Council, 2001).

According to Tomlinson and McTighe (2006), the strength of the UBD lies on the instructional design model it offers. UBD model emphasizes the students understanding of concepts and the backward design acknowledges not only the centrality of standards but also demonstrates the meaning and understanding content standards. In this way, Castillo (2015) suggests that students can construct meaning from facts they acquire and able to use it.

Table 3. Summary on the Perception of the Effectiveness of CAI on the aspects of Motivation, Concept Formation, Application and Retention in Learning Special Products and Factoring

Learning Aspects	Overall Weighted Mean	Descriptive Rating	Rank
Motivation	4.10	Very Effective	4
Concept Formation	4.34	Very Much Effective	1
Application	4.17	Very Effective	2.5
Retention	4.17	Very Effective	2.5
Grand Mean	4.20	Very Much Effective	

The Computer-Aided Instruction was perceived to be very much effective in learning special products and factoring on the aspect of concept formation which ranked first with overall weighted mean of 4.34 (Table 3). Application and retention ranked 2.5th. The aspect of motivation was fourth in rank. The CAI was perceived to be very much effective with grand mean of 4.20. Pilli and Aksu (2013) found that the educational software is an effective tool for teaching and learning mathematics in the sense that pupils who used the software in the classrooms achieved higher test scores and had more positive attitudes towards mathematics. Aral and Ayhan (2005) also found significant effects of computer-assisted instruction in the concept development of children who were exposed to the training without any assistance from teachers and still understood the lessons and performed well in a given activity. Furthermore, Pilli (2008) showed statistically significant difference in favor of computer-based learning on tests retention. Evidence indicates that Frizbi Mathematics 4, a computer-based lesson for learning and teaching mathematics is an effective tool in the construct retention of the students.

Table 4. Comparison of Perception on the Effectiveness of UBD and CAI on the aspects of motivation, concept formation, application and retention

Learning Aspects	UBD	Descriptive Rating	CAI	Descriptive Rating
Motivation	3.81	Very Effective	4.10	Very Effective
Concept Formation	4.07	Very Effective	4.34	Very Much Effective
Application	3.87	Very Effective	4.17	Very Effective
Retention	3.81	Very Effective	4.17	Very Effective
Grand Mean	3.89	Very Effective	4.20	Very Much Effective

The results show that for both UBD and CAI, concept formation ranked first among the learning aspects. Concept formation was perceived to be very effective for UBD and was very much effective for CAI (Table 4).

Difference in the Students' Perception between the Effectiveness of UBD and CAI in terms of Motivation, Concept Formation, Application, and Retention

There is significant difference in the students' perception on motivation between UBD and CAI. It was observed that the learning tasks in special products and factoring were seen by students as more meaningful and worth learning in CAI than UBD.

While the mean perception level (4.07) using UBD is less than (4.34) using CAI, there was no difference in the effectiveness of UBD and CAI in concept formation ranging from simple to more complex topics on learning special products and factoring. It was observed that the procedures used in concept formation such as providing stimulus, constant drill and practice, enhancing meaningfulness, use of elaboration and emphasizing rules for both UBD and CAI were perceived by the respondents to be equally effective.

On the other hand, the level of significance indicates that there was no significant difference in the perception of respondents on the effectiveness of UBD and CAI in learning special products and factoring. In this study, the respondents perceived that CAI was very much effective in enhancing the application of learning by providing a variety of problems to solve. The UBD was very effective in enhancing the application aspect by reinforcing the use of techniques learned in solving problems.

Finally, there was a significant difference in the perception of respondents on the effectiveness of UBD and CAI in learning special products and factoring in terms of retention. Instruction should be understood and remembered. There is better retention of information through CAI as illustrated by the higher mean perception value (4.17).

Roschelle *et al.* (2010) identified a positive significant impact on the use of the CAI program on pupils' mathematics achievements. The authors conclude that the CAI is an effective tool to enhance pupil knowledge of more advanced mathematics. Moreover, Castillo (2015) reiterated that the students' participation in CAI-based learning leads to higher test results, concluding that CAI is, therefore, effective than traditional instruction.

Moreover, the study examined whether a higher exposure to the program leads to higher test outcomes, using an instrumental variable approach. We observed that, given the participation to the CAI-tool, making more exercises leads to higher test results. Working with a CAI-tool, is, therefore, effective.

Difference between UBD and CAI in terms of Pretest and Posttest Mean, Median and Modal Scores

The data on t-test to test the difference of the pretest and posttest mean, median and modal scores respectively between UBD and CAI are presented in Table 5 and Table 6.

Table 5. T-test of Difference of the Pretest Mean, Median and Modal Score between UBD and CAI in Learning Special Products and Factoring

Statistics	UBD		CAI	Decision	Interpretation
Standard Deviation	1.75		3.30		
Number of Respondents	50		50		
Degrees of freedom (df)		98			
Level of Significance (α)		0.05			
Mean	**7.94**		**10.76**		
t-critical		1.645		**Reject Null Hypothesis**	**Significant**
t-computed		7.500			
Median	**8**		**10**		
t-critical		1.645		**Reject Null Hypothesis**	**Significant**
t-computed		5.320			
Mode	**8**		**9**		
t-critical		1.645		**Reject Null Hypothesis**	**Significant**
t-computed		2.660			

There was a significant difference between the pretest mean, median and modal scores of the students in special product and factoring. The significant difference in the pretest mean, median and modal scores can be attributed to the nature of the students in each class. As reflected from the above data, students who took CAI performed better than students who took UBD. These findings are consistent with those of the results obtained in the study comparing the effectiveness of computer-assisted instruction and traditional classroom lecture in allied health sciences where the participants in the computer-assisted group gained more knowledge based on pretest and posttest scores than participants in the traditional classroom lecture group (Galvis, Ishee & Schultz, 2011). As cited by Izard (2005), pretesting though simple and basic assessment tool distinguished students between those who have the required knowledge and those who do not.

Table 6. T-test of Difference of the Posttest Mean, Median and Modal Score between UBD and CAI in Learning Special Products and Factoring

Statistics	UBD	CAI	Decision	Interpretation
Standard Deviation	4.01	3.87		
Number of Respondents	50	50		
Degrees of freedom (df)	98			
Level of Significance (α)	0.05			
Mean	**10.46**	**14.80**		
t-critical	1.645		**Reject Null Hypothesis**	**Significant**
t-computed	5.508			
Median	**10**	**15**		
t-critical	1.645		**Reject Null Hypothesis**	**Significant**
t-computed	6.345			
Mode	**5**	**11**		
t-critical	1.645		**Reject Null Hypothesis**	**Significant**
t-computed	7.614			

There was a significant difference between the posttest mean, median and modal scores (Table 6). It was reported in the study of Vinita and Banswal (2015) that the main effect of CAI on students' retention is very positive. Learning with animation, sounds and images has a positive impact on student learning. The authors found significant difference in favor of CAI. According to this result, CAI is more effective than traditional instruction. The difference between gain levels increased almost nearly two times highly in favor of experiment group.

Relationship between Test scores and Perception on the Effectiveness of UBD and CAI

Computer-generated Pearson-r value using Microsoft Excel 2007 software indicated that there was moderately low positive correlation between pretest scores and the weighted mean of perception on the effectiveness of UBD (See Table 7).

Table 7. T-test for Significance of Relationship of Pretest Scores and Perception on Effectiveness of UBD in Learning Special Products and Factoring

Statistics	Pretest vs Effectiveness	Posttest vs Effectiveness
Number of respondents (n)	50	50
Degrees of freedom (df)	48	48
Pearson-r	0.44	0.42
Level of Significance (α)	0.05	0.05
t critical	2.576	2.576
t computed	3.780	3.205
Decision	Reject Null Hypothesis	Reject Null Hypothesis
Interpretation	Significant	Significant

The computer-generated Pearson-r value indicated that there was moderately low positive correlation between pretest scores and the weighted mean of perception on the effectiveness of UBD while there was moderately low positive correlation between posttest scores and the weighted mean of perception on the effectiveness on UBD. The null hypothesis that there is no significant relationship between pretest and posttest scores and the perception on the effectiveness of UBD is rejected. The results provide similar insight on the findings of the study of Ali and Elfessi (2004) comparing the performance of students in traditional (with online supplement) and online classes. It was reported in the study of Ali and Elfessi (2004) that the learning environments and the instructional medium have minimal impact on student learning. The study also found out that the slight score improvement the traditional group gained over their online counterparts might be the advantage of having face-to-face instruction. It was observed that personal interaction between and among the respondents, and the presence of the teacher in the UBD-based instruction provided challenge and encouraged the students to do their best to find solution and answers to the problem solving activities for the topic on special products and factoring.

Table 8. T-test for Significance of Relationship of Pretest Scores and Perception on Effectiveness of CAI in Learning Special Products and Factoring

Statistic	Pretest vs Effectiveness	Posttest vs Effectiveness
Number of respondents (n)	50	50
Degrees of freedom (df)	48	48
Pearson r	0.23	0.06
Level of Significance (α)	0.05	0.05
t critical	2.576	2.576
t computed	1.680	0.146
Decision	Accept Null Hypothesis	Accept Null Hypothesis
Interpretation	Not Significant	Not Significant

The computer-generated Pearson-r value indicated that there was very low positive correlation between pretest scores and the weighted mean of perception on the effectiveness on CAI while there was very low positive correlation between posttest scores and the weighted mean of perception on the effectiveness on CAI. The null hypothesis that there is no significant relationship between posttest scores and the perception on the effectiveness of CAI is accepted (Table 8).

The correlation of both pretest and posttest scores respectively and perception on effectiveness of CAI was very low positive and not significant was in contrast to the findings of the study in Korea which reported that e-learning in vocational education was as effective as face-to-face learning (Park *et al.,* 2006). While the studies of Wang and Bagaka (2002), and of Redding and Rotzien (2001) revealed that computer applications on the Internet as an instructional tool has the potential to improve learning, Kincannon (2002) found that learning online using computer application requires more time than traditional learning. It was observed that the respondents in the CAI-based instruction admitted that the use of the computer software did not provide enough challenge to the students. This results also contradict the study of De Witte, Haelermans and Rogge (2015) which suggests that the use of CAI-programs to catch-up on learning outcomes is promising. Moreover, the authors argue that the participation on CAI program leads to higher test results.

CONCLUSIONS

The study concludes the pretest scores for both UBD and CAI were consistently lower that the posttest scores. The pretest and posttest mean, median and modal scores were higher using CAI compared to UBD-based instruction. Understanding by Design instruction was perceived as very effective in terms of concept formation followed by application, motivation and retention. Computer aided instruction was also perceived as very effective in terms of concept formation followed by application and retention, and motivation.

The null hypotheses that there are no significant differences in the effectiveness of UBD and CAI in learning special products and factoring in terms of motivation and in terms of retention is rejected. While the null hypotheses that there are no significant differences in the effectiveness of UBD and CAI in learning special products and factoring in terms of concept formation and in terms of application is accepted. Also, the null hypotheses that there are no significant differences in the pretest and posttest mean, median and modal scores respectively between UBD and CAI is rejected.

In terms of significant relationships, the null hypothesis that there is no significant relationship between pretest scores and the perception on the effectiveness of UBD, and between posttest scores and perception on the effectiveness of UBD is rejected. Lastly, the null hypothesis that there is no significant relationship between pretest scores and the perception on the effectiveness of CAI, and between posttest scores and the perception on the effectiveness of CAI is accepted.

The salient finding of the study is that the CAI should be used to supplement UBD-based instruction in Mathematics 2, particularly, in classes consisting of heterogeneous groups of students. The study also emphasizes that more hands-on exercises in Mathematics II competencies which are difficult to comprehend and less interesting should be given to homogenous students using UBD-based instruction. Identified lessons and activities in Mathematics 2 where more students got low score than high score must be considered an area for further studies. Furthermore, a similar study should be done using UBD-based instruction for academically-gifted students. Finally, a similar study should be done using UBD-based instruction supplemented with CAI for academically-challenged students.

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