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Research Studies of Computer-assisted Instruction in Mathematics Education: Examination of Turkish Graduate Theses Completed between 2005-2016

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Abstract: The rapid development and diffusion of technology dramatically change the power balances/relations and competition areas among the countries. In order to keep up with such a transformation and to become an arbiter or an entitled shareholder, countries strive to get benefit from the latest technology in their all institutions. Intensive effort and studies are being conducted especially on the information and technology oriented economy and growth. One of the fundamental requirements for success in this issue is to train entrepreneur citizens that are aware of the potentials of technology and able to use technology for production through integrating technology in educational contexts. Computer-assisted instruction (CAI) is one of the applications to help in the way of fulfilling this goal. Defined as making use and taking the advantage of computer technologies in teaching-learning activities, CAI aims to provide students with effective and enriched educational experiences that can ideally serve their needs and interests. Computers are also used in mathematics education where analytic processes such as calculation, visualization, prediction and intuition, modeling and generalization are required. The potentials of CAI in mathematics education have been explored in research studies. Examination of these studies is important in order to follow rapidly changing computer applications and related research trends in this area. Therefore, using a content analysis, this study aims to provide an overall evaluation of Turkish graduate thesis focusing on the use of CAI in mathematics education completed between 2005 and 2016. A total of 83 theses were recruited through relevant searches on the online database of Higher Education Council. They were carefully read and the necessary information was transferred to the Microsoft Excel environment using the 4N1K literature review method. Then, the information about each study was coded in terms of research problem, CAI application employed, main variables, research methods, sampling, data collection and analysis methods and results and then converted into frequency and percentage tables.

Keywords: Mathematics education, Computer-supported instruction, Graduate thesis, Content analysis

Introduction

In the information age, we are experiencing very rapid advances in technology and its implementation in every aspect of our lives. In line with these advances, technology has also entered our education systems. In earlier times, the main and central element in education was the teacher, and his/her companion was the classroom and the blackboard. In time, the blackboard and chalks were replaced by whiteboard and felt-tip pens respectively. Recently, interactive boards, tablet computers and instructional software have started to take part in education.

Individuals usually attempt to handle, minimize or overcome the problems with which they face during their lives. The tools and characteristics they own including their education are the biggest support in this endeavor. One of the objectives of the education is to increase the number cells working in the human brain, which is possible with thinking. Mathematics is the primary subject that teaches how to think (Kart, 2002).

Various objectives are determined to improve the quality of mathematics education at every stage of the education system. Possessing mathematical concepts, gaining problem solving skills, having confidence in mathematics, and gaining a positive attitude towards mathematics are some of these goals (Baydar & Bulut, 2002). In order to achieve these objectives, computer-assisted mathematics teaching can be implemented as an instructional strategy by using the advances in educational technology.

As a general concept, computer-assisted instruction briefly means some way of benefiting from the computer and its applications in the teaching and learning processes in the schools. Its purpose is to provide students with an effective and rich learning-teaching experience that will best meet their interests and needs. The rationale for using such a strategy includes but not limited to being able to catch up with the changes and increases in today's knowledge base (lifelong learning), sustaining in the technology-intertwined society (networked or digitalized community), necessity of using information and communication technologies in every profession (21st century skills), and increased demand for education (distance education, personalized learning). Some potentials of using computers in education consist of multimedia, individual learning, visualization, enriched interaction, quick feedback, repeated use, safe observation, high motivation, and time and resource saving (Yanpar, 2007). The variety of computer-assisted instructional applications can be grouped under such categories as drill-and-practice, tutorial, simulation, instructional game, and problem-solving (Doering & Veletsianos, 2009).

The use of computer as a cognitive tool in mathematics teaching is called computer-assisted mathematics instruction (Baki, 2002). The more important feature of the computer than it can be used as an effective computing tool in the teaching process is that it can carry the abstract mathematical concepts to the screen and embody it (Baki, 1996; Özdemir & Tabuk, 2004). Therefore, today's teachers are expected to integrate educational technologies to train individuals who have effective thinking habits such as analytical and critical thinking. Similarly, scholars in mathematics education field are also expected to scientifically investigate the potential consequences of using computer applications on students' mathematical outcomes.

As known as a general rule of research, a new scientific study that will be conducted in any field takes its theoretical and methodological base from the related studies already completed and interprets its findings in this context. Such an approach helps researchers know previous problems, theoretical foundations, research methods and techniques. The detailed examination of prior studies is important in terms of evaluating the historical development of the related field, determining the current issues and trends, and directing possible future studies. It is especially crucial in areas such as educational technologies that show rapid development and change. In fact, it is thought that it will be useful to periodically analyze the information that is in continuous change and to apply it in research and development as well as teaching processes. Moreover, it will assist new master and doctorate students to concentrate on original and contemporary research topics in their academic studies. With this in mind, this study aims to survey and analyze the empirical literature related to the application of computer-assisted instruction in mathematics education. It is limited to studies which were conducted in Turkey, written in Turkish language, prepared as a graduate thesis (master and doctoral), completed in the last decade (2005-2016). The following main questions guided this study:

1. How was the number of studies distributed across the years?
2. What were the research problems and main variables?
3. What kinds of computer-assisted applications were employed?
4. How were their research problems investigated in terms of research designs, sampling strategies, data collection approaches, and data analysis techniques?

Method

This study was designed as a historical survey which involved document analysis. In these type of research studies, researchers usually employ content analysis techniques to review written materials (diaries, newspapers, official documents, compositions, etc.) that contain information about the cases that are intended to be investigated. The rich data contained in these documents are very effective in describing the research topic in a multifaceted way and in determining how it develops in the historical process (Cohen, Manion & Morrison, 2007).

Turkish master and doctoral thesis completed between 2005 and 2016 were treated as documents or data sources for this study. These theses were recruited through online searches on the database of National Dissertation Center managed by Turkish Higher Education Council. The abstracts of dissertations were carefully read to

determine their suitability to be selected as a data source. After this initial review, a total of 83 studies were selected as appropriate for further investigation.

Collected theses were analyzed using descriptive content analysis, which consists of such stages as (a) coding the data, (b) creating possible themes, (c) organizing themes, and (d) presenting findings (Yıldırım & Şimşek, 2011). Textual content analysis often involves the elucidation of meaning and conclusions from texts through the reduction of large-scale texts with many words to summative themes with fewer words and categorization of similar themes under common conceptual structures (Weber, 1996). In this study, each thesis was thoroughly read and an annotated bibliography was created by coding their texts in accordance to the research questions. Next, a database of coding results was developed in MS Excel. The results were then presented by using frequency tables and graphs.

Results and Discussion

The distribution of the number of theses by years is given in the line graph in Figure 1. As can be seen from the graph, the number of studies was stable until 2009 and it sharply increased in 2010 and made a peak in 2011. It remained high and stable in 2012 and 2013 but dramatically decreased in 2014. Hence, there was a jumping/inflation in the numbers between 2010 and 2013. When the changes between the years are examined, the rapid increase in the number of theses between the years 2005 and 2006 (500%) and the decrease between 2013-2014 (54.5%) are significant. The increase between 2009 and 2011 (180%) can be explained by the fact that the FATIH Project was started in 2010. In other intervals, gradual increases and decreases are observed.

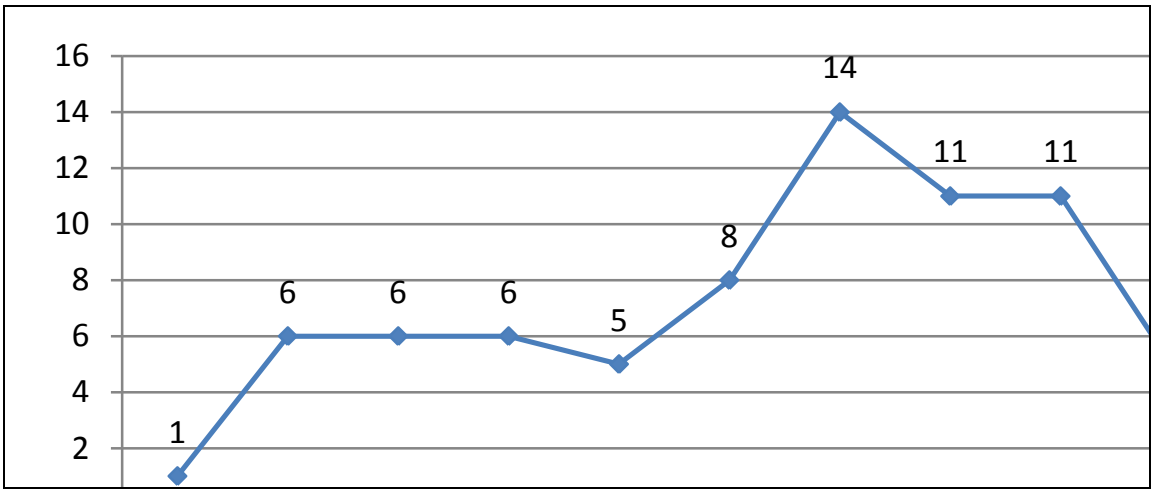

Figure 1. The number of thesis across the years

The majority (actually almost all) of them are empirical studies which based on the collection and analysis of some sort of data. A few of them were theoretical ones like instructional designs, modeling and discussions. Only two were review studies including chronological analysis and comparisons.

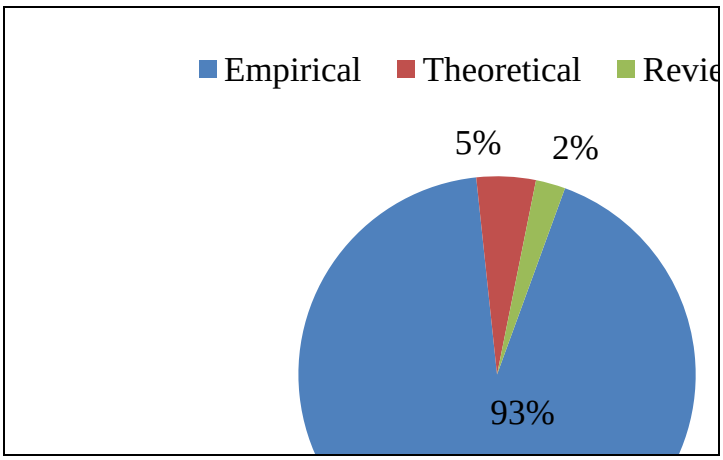

Figure 2. The distribution of research approaches

For example, the problem of a theoretical study is "how should a computer-assisted instructional design of the permutation and probability unit be designed in the 8th grade mathematics education curriculum?". One of the two review studies examined historical development of computer-assisted mathematics education and the remaining investigated the comparison of open source software used in mathematics education.

The distribution of research methodologies employed in the theses is presented in Table 1. Half of them employed quantitative, a one third employed qualitative (this is interesting for math researchers), and almost a quarter of them used mixed methods. All quantitative studies were experimental in nature, which include the manipulation of independent variables, mostly in the form of using computer-assisted instructional applications in math courses, and then observing possible consequences on some dependent variables. Regarding experimental designs, only two were true experiments with randomized assignments of subjects. The remaining was almost evenly distributed as quasi and poor experiments. No studies were found descriptive in nature. For those who employed qualitative research approaches, a little more than half were designed as a case study and the remaining were equally distributed as grounded theory and action research.

Table 1. The distribution of research methodologies

Research paradigm	Research model	f	%
Quantitative	True experimental	2	2.4
	Quasi-experimental	20	24.1
	Weak experimental	19	22.9
	Single subject experimental	1	1.2
Qualitative	Grounded theory	5	6
	Case study	14	14.5
	Action research	5	6
Mixed		16	19.3

Table 2 demonstrates the sample distribution of theses. The range of subjects was quite diverse. However, the most focused population was secondary school students (almost half), followed by undergraduate students (a quarter), and high school students. Only two studies explored graduate students including both master and doctoral levels. As far as the sample size was concerned, most of the studies were conducted on relatively small samples with no more than 50 students. In fact the majority (91%) were carried out with 0-100 participants. This is because of the fact that most used experimental and qualitative models.

Table 2. Sampling by level of education

Sample	f	%
Primary education	5	5.7
Secondary education	37	42.5
High school	14	16.1
Undergraduate	20	23
Graduate	2	2.3
Instructor (teacher, academician)	6	6.9
Other	3	3.5

The distribution of computer-assisted instructional applications is shown in Table 3. The dominant type of computer-assisted instruction in the studies is tutorial (instructional software that is specially programmed to teach content knowledge), followed by problem solving applications. Simulation includes augmented reality; drill-and-practice helps students to perform lower level skills automatically. Computer games allow students learn math concepts and skills by playing and entertaining. Tutorials included GeoGebra, Cabri, Geometer's Skechpad, Derive, MS Excel, and so on. GeoGebra, Derive, Maple, Cabri, 3D Studio Max and Geometer's Skechpad were also employed for problem-solving. Regarding those theses used computer game, one employed 3D Minecraft game and the other employed researcher-developed games based on Java and Netbeans.

Table 3. Computer-assisted instructional applications used in the theses

Application	f	%
Simulation	1	1
Tutorial	88	87.1
Problem-solving	8	7.9
Drill-and-practice	1	1
Computer game	2	2
Other (Webfolio)	1	1

Figure 3 summarizes the number of variables studies in the theses. The most investigated variables were achievement (represent the comprehension of math concepts), attitude (including motivational characteristics of math content), students' satisfaction from computer-assisted instructional applications, and higher order thinking skills such as criticizing, analysis, synthesis, logic, creativity and so on. As expected, these variables were treated as dependent/outcome variables in the thesis. The usability category involved the usability or functionality of the computer-assisted applications used in the studies.

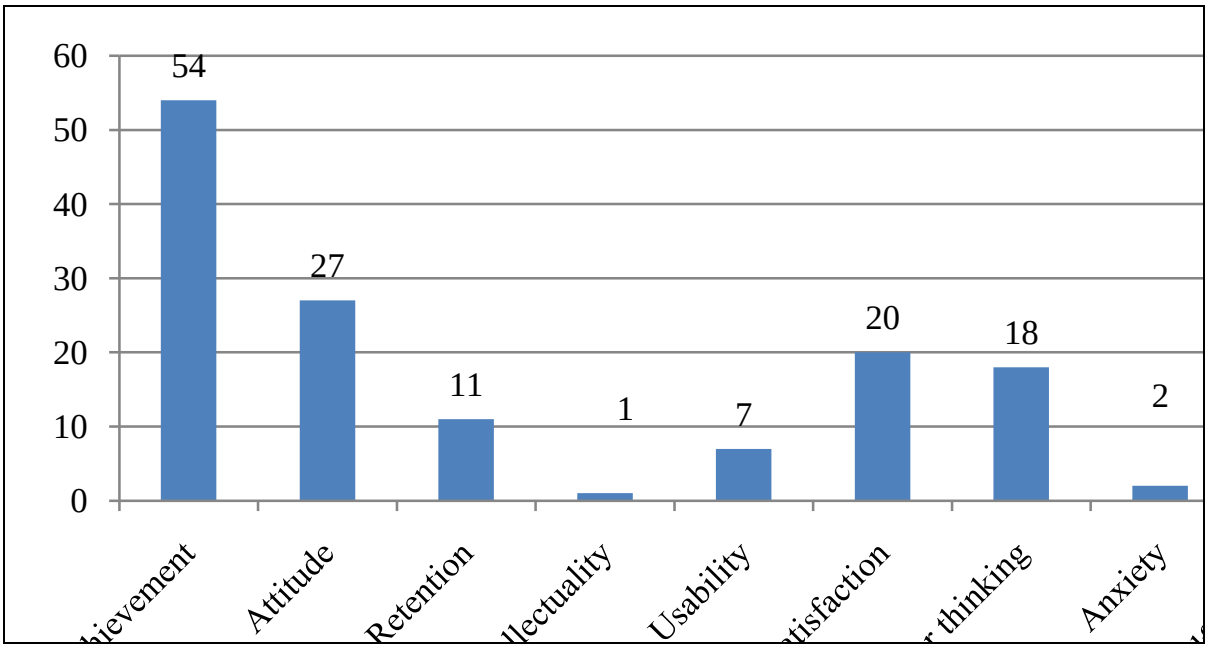

Figure 3. Variables investigated in the theses

The distribution of data collection tools employed in the theses is presented in Figure 4. As expected, the usage of data instrumentation was dependent on the variables investigated. The most frequently employed tools were achievement test (31%), scales (especially measuring affective/motivational characteristics), interviews with those students who used computer-assisted instructional applications, and observations including students' usage of these tools and tracking their eye movements. Documents included scientific reports, student artifacts, alternative measures such as webfolio and self-evaluation reflections. The majority of the achievement tests and scales included multiple-choice and Likert-type questions respectively. Most interviews were semi-structured. Ability testing instruments included mental rotation test, spatial visualization test, and number sequence memory test.

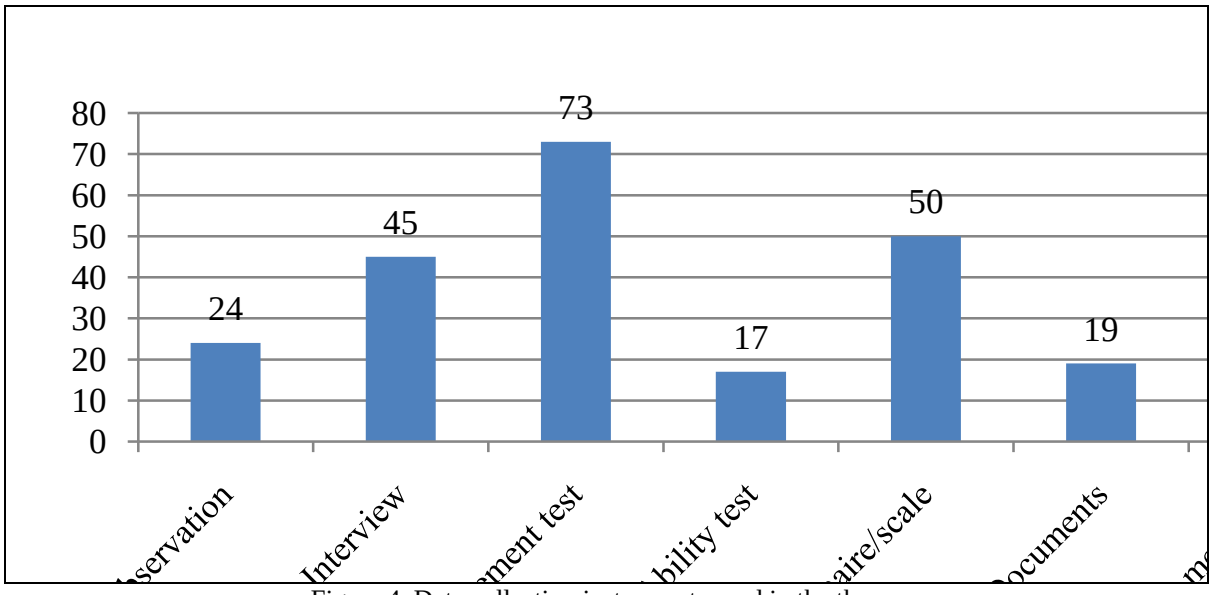

Figure 4. Data collection instruments used in the theses

Table 4 shows the distribution of data analysis techniques utilized in the theses. Most studies applied descriptive statistics including frequency analyses, central tendency and dispersion to summarize their variables. Almost all studies applied inferential stats to examine relationships and differences among the variables. Of these, t-tests were the most employed technique followed by ANOVA tests. Qualitative studies utilized content analysis techniques.

Table 4. Data analysis techniques employed in the theses

Technique	f	%
Frequency and percentage	15	7.7
Mean and standard deviation	21	10.8
Data visualization	7	3.6
t-test	45	23.1
ANOVA	14	7.2
ANCOVA	7	3.6
MANOVA	2	1
MANCOVA	3	1.5
Correlation/regression analysis	12	6.1
Factor analysis	2	1
Non-parametric tests	20	10.3
Content analysis	47	24.1

Conclusion

The number of Turkish graduate thesis focusing on using computer-assisted instruction in the field of mathematics education has been increasing by 2010. The inflation between 2010-2013 can be explained by the start of FATIH project. FATIH is a nation-based reform through which all classrooms were equipped with interactive boards and students were given a tablet PC. Also, a big depository of instructional software and materials, which is called EBA, was open to teachers' usage. Professional development programs about technology integration were offered to teachers as well. Therefore, this obviously attracts mathematic education scholars to conduct technology-related research studies. Almost all theses examined in this study utilize tutorials. Future studies should be canalized to simulation, problem-solving apps and games, which are known to be useful for mathematical reasoning.

Quantitative research methods, especially experimental designs with small samples are prevalent among the thesis. Scholars are mainly interested in comparing traditional teaching methods with technology enhanced ones. No descriptive design within the quantitative research paradigm was employed. Hence, future studies can focus on larger scale surveys to explore associations among the variables.

Theses frequently explore the possible effect of computer-assisted instruction on math outcomes of students enrolled in fifth grade to university. Future studies may focus on investigating the potentials of computer-assisted instruction on primary school students' (1-4 grade) math learning. Achievement and attitude seem to be adequately studied. Future studies should give more attention to math variables such as anxiety and higher order thinking skills.

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