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Original Research Article

Effectiveness of Educational Technology Applications for Enhancing Mathematics Learning in Saudi Secondary Schools

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Abstract

This paper examined the effectiveness of educational technology applications for enhancing mathematics learning in Saudi secondary schools. It was guided by the following research questions. Firstly, does the use of the educational technology applications improve mathematics learning in secondary schools? Secondly, what is the role of the educational technology applications in learners' understanding? Thirdly, what measures has the government of Saudi Arabia applied to support the effective use of educational technology applications in mathematics learning in the secondary schools? Finally, what steps should the government of Saudi Arabia take to improve the use of educational technology applications for learning mathematics in secondary schools? Both qualitative and quantitative approaches were used to examine the effectiveness of educational technology applications in 15 secondary schools in the Northern Borders region of Saudi Arabia. Questionnaires, interviews, and observations of the mathematics learning process were used as data. The research concluded that the applications improve learners' understanding of mathematics. Educational technology applications helped in the computation of mathematical problems, triggered students' problem-solving skills, and prepared them to handle and address various challenges in society. Moreover, I provide policy suggestions for the Saudi government to improve efficiency in implementing these technologies.

Keywords: Educational technology applications, learning, secondary school education, Saudi Arabia, mathematics education

INTRODUCTION

Background of the Study

Technological development has enormously impacted learning processes in educational institutions. The 21st century has been marked by numerous changes in technology, which have influenced scholarly understanding of learning and teaching methodologies and teaching in various ways (Cheung and Slavin, 2011). In the past, people relied on functional calculators for mathematical computations; however, calculators could only compute simple problems. The emergence of computers and educational technology applications has boosted mathematical performance and enhanced the provision of quality mathematical education at the secondary level (Kissane et al., 2015). Technological applications emerged from information and communication technology (ICT). ICT was first used in developed nations such as the US, the UK, Singapore, and Germany (Kissane et al., 2015). Technology is used to provide education in most countries (Clements et al.,

2013). Educational technologies are widely used in developing nations to counteract teacher shortages because of growing numbers of learners (Hoyles et al., 2010).

Saudi Arabia is a developing country that has made significant progress in delivering the best education. Today, most social sciences and arts lessons involve ICT (Hoyles et al., 2010). This system has been extended to secondary schools with intention of improving learning of mathematics education. Hence, this study will focus on the "effectiveness of educational technology applications for enhancing mathematics learning in Saudi secondary schools." The focus will be on current technological applications that can be used in teaching particular topics in mathematics. This paper particularly discusses the technological applications that help students to compute, solve mathematical problems, or explain how certain mathematical issues are computed. These applications are installed on computers and their effective use depends on the students' computer knowledge. Some of the latest technological applications include math apps and e-textbooks, mathematical video tutorials, spreadsheets, math space, integrated learning systems (ILS), computer assisted instruction (CAI), and technology-based circular. Technology applications are capable of demonstrating how mathematical problems can be handled (Hoyles et al., 2010). I will conduct an intensive literature review concerning the use of educational technology applications to ascertain how Saudi Arabia can maximize the benefits of the plan in secondary schools and develop the program effectively.

Statement of the Problem

Since the development of calculators in the1970s, many technological changes have enhanced the transferral of knowledge in mathematics classes. Goos (2010) outline show the emergence of computers led to the development of mathematical software: applications and graphic calculators simplified the handling of mathematical problems. The development of technological applications led to graphic integration, symbolic manipulation, and the provision of virtual learning environments. Consequently, these changes improved mathematical teaching techniques and learning terrain (Goos, 2010).

Moreover, technology is omnipresent in contemporary society. Tremendous changes in technology triggered the need to develop educational systems that appropriately prepare learners for industrial requirements. However, the focus should not be limited to the acquisition of educational technology applications; it is equally crucial to development measures to improve the use of these applications and to help learners solve mathematical problems (Cheung and Slavin, 2011). Naturally, most learners are uninterested in mathematics because of computation and the interpretation of complexities (Masschietto and Trouche, 2010). Furthermore, some mathematical problems torture learners' minds despite lacking applications in the current economy (Guo and Cao, 2015). Developing educational technology applications (ETAs) but failing to apply them appropriately in secondary schools would not yield the desired results. Therefore, the government of Saudi Arabia should conduct studies to uncover effective ways of implementing ETAs to enhance learning at the secondary level (Almaki et al., 2013).

Purposes and research questions

The research aimed to examine the effectiveness of ETAs for enhancing mathematics learning in Saudi Arabian secondary schools. It intended to give recommendations of steps for the government to take to improve the implementation of ETAs in secondary schools. The Saudi Arabian government formulates the policies that are intended to aid the effective adoption of ETAs in mathematics education (Chai et al., 2013). This adoption of ETAs is successful when potential barriers to the implementation of policies are eliminated. Therefore, the following research questions were applied to ascertain the effectiveness of ETAs in secondary schools.

a) Does the use of ETAs improve mathematics learning in secondary schools?
b) What is the role of ETAs in learners' understanding?
c) What measures have the government of Saudi Arabia applied to support the effective use of ETAs in mathematics learning in secondary schools?
d) What steps should the government of Saudi Arabia take to improve the use of ETAs in mathematics education in secondary schools?

LITERATURE REVIEW

Theoretical Framework

Phenomenographic and variation theories

Pierce and Stacey (2010) apply these theories to explore different aspects of learning such as context, social interaction, and cognition. They argue that technological application and research in education undertaken on the basis of these theories must scrutinize or evaluate alternatives. However, they do not conclude that ETAs significantly contribute to learners' understanding more than traditional systems. In Guo and Cao's (2015) phenomenographical examination of educational phenomena using qualitative methods, they conclude that ETAs somewhat improve mathematics learning. Graham (2011) asserts that variation theory helps guide learners

and informs students about various aspects of the learning objectives. This scholar examines the relevance of variation theories to mathematics education in schools using qualitative and quantitative methods; he argues that ETAs play a crucial role in enhancing students' understanding. These studies reveal that the effective integration and implementation of ETAs will aid students in learning mathematics.

Phenomenographic and variation theories are crucial for this study. They are important for defining and explaining aspects of effective learning processes. They help us comprehend the plight of teachers and governments as they try to enhance the efficiency of learning process. In previous studies, phenomenographic and variation theories have been used to describe learning systems used in schools, student participation, and the effectiveness of the learning approaches used. Phenomenographic and variation theories further explain how and why learning institutions should use ETAs in teaching science and mathematics subjects (Guo and Cao, 2015). Therefore, it is indisputable that they are essential for this study's evaluation of the effectiveness of ETAs, in secondary schools specifically.

Constructivism theory

Stacey and Wiliam (2013) employ constructivism theory to emphasize the proximity between technology and its use in education. They explore whether technology can be applied as learning design in various institutions, finding that learning occurs in context, and incorporating technology in learning mathematics positively impacts students' understanding. Almaki et al. (2013) relate constructivism theory to psychological and physiological approaches based on social cognitivism. Their study examines whether the behavior of learners is directly influenced by their experiences and the environment in which they interact. They conclude that learning is a socially dependent construction not limited by an individual's development age. Artigue (2010) applies constructivism theory to determine its role in the actual construction of personally relevant projects, concluding that learners personally construct knowledge. This theory explains why incorporating ETAs into mathematics education is a prerequisite in contemporary society. Today, learners are directly influenced by the widespread use of technology in various life aspects of life. This study applies constructivism theory to emphasize the need to adopt ETAs in secondary schools.

Moreover, Artigue's study found that learning is a self-regulated process that results from individuals' interactions with their environment. According to Chai et al. (2013), individuals formulate unique ways of thinking due to innate capabilities of interactive with their environment and their experiences. The latter ultimately make learning a non-stimulus response phenomenon. Additionally, Cheung and Slavin (2011) apply constructivism theory to conclude that learners construct conceptual structures through abstraction and reflection.

This study deploys constructivism theory to examine the ways in which knowledge is acquired and conceived, which activities are emphasized, how goals are established, and how skills develop with regard to ETAs in mathematics (Stacey and Wiliam, 2013). Currently, technology is a prerequisite in most aspects of life: the rapid development of technology has substantially changed the social, political, environmental, and economic arenas. This change is equally experienced in education. Therefore, this study uses constructivism theory to justify the need for ETAs in teaching mathematics in secondary schools, as well as to defend the recommendations given on what the government should do to ensure ETAs are effectively used in teaching mathematics across Saudi Arabia.

Complexity theory

Goos (2010) examines how this theory is applicable in mathematics education. He applies qualitative methodology to reach the conclusion that the learning system under complexity theory advocates various principles, such as internal diversity, redundancy, distributed control, organized randomness, and neighbor interactions. With the integration of these elements into learning systems, it is appropriate to assess teachers' roles in enhancing students' understanding. Goos (2010) further deploys complexity theory to point out how learning can happen outside of the classroom. Such as in online communities of practice and gaming scenarios using ETAs. This study shared similar findings with Cavanagh and Mitchelmore (2011), who observe that the Ministry of Education could use complexity theory to formulate appropriate measures for enhancing the efficient use of ETAs in secondary school mathematics teaching.

In this study, complexity theory is important to underpin the potential downsides of applying ETAs in teaching mathematics at the secondary level. It is used in the analysis section to explain teachers' opinions on the effects of this technology on learning mathematics. Also, this study primarily aims to examine the effectiveness of ETAs in teaching mathematics in high schools. Complexity theory plays a pivotal role in describing how this technology improves learning over traditional approaches.

Conceptual Frameworks (Previous Work on ETAS)

Forster (2007) defines ETAs as a variety of technology-based programs that support instructors in de-livering learning materials. Regarding efficiency, there are

applications that improve academic learning goals in mathematics. Examples of ETAs include: integrated learning systems (ILS), computer assisted instruction (CAI), and technology-based circular. While calculators are one of the technologies used in mathematics, they are not classified as tools. Furthermore, various studies have concluded that ETAs are helpful for learning, especially if the program is efficiently implemented (Hollebrands, 2007). Masschietto and Trouche (2010) also conclude that ETAs significantly benefit learners. These scholars explain that integrating technology into secondary level mathematics education will increase learners' understanding of mathematical concepts and motivate them to focus more on their discipline. ETAs yield the best results when learners are given adequate guidance on how to use the technologies.

Drijvers et al. (2010) outline how the government influences the provision of education through offering technical support, financial resources, staff training, ETA policy, and supervision. Most studies conducted on this topic undoubtedly conclude that ETAs have positive effects on mathematical achievements among learners (Ruthven et al., 2009). These findings are helpful for the Saudi government, since they can be used as a basis for constructing rules concerning the effective adoption of ETAs in secondary schools. A review of previous literature indicates the effectiveness of ETAs in mathematics education, though the interpretation of such studies needs to be handled with care (Joubert, 2013). Issues such as which procedures were used and how the data were analyzed ought to be considered to help us obtain practical information about the problem. Other studies are characterized by poor research methodologies, which tend to hinder the formulation of realistic results. Therefore, the limitations of previous studies, including short duration, lack of a control group, lack of initial equivalence, and cherry-picked evidence, justify the need for more research on the topic (Graham, 2011). Finally, these studies have not explored the use of ETAs in learning mathematics in Saudi Arabia, further reinforcing the need for future studies.

RESEARCH METHODOLOGY

Both qualitative and quantitative methods were applied. A mixed approach was used to help us understand the effectiveness of ETAs in enhancing mathematics learning in secondary schools in the Northern Borders region. This section comprises the following: research design, population and sample size, sampling methods, data collection techniques, and data analysis. Through these subsections, I describe how the information was gathered, analyzed, and finally presented.

Research Design

A qualitative approach allows the use of various methods to collect descriptive data, providing a deeper understanding of the phenomenon. Data were gathered using interviews and observation. Interviews were held with key stakeholders in the Saudi Ministry of Education and the ETA Implementation Department, while efficiency in the learning process was observed in 15 schools. Interview questions were designed to help obtain respondents' opinions about the usefulness, implementation, and effectiveness of ETAs in secondary schools. The interviews were administered by two consultants residing in the Northern Borders region. Afterwards, content analysis was used, and the results were presented, as shown in the next chapter. On the other hand, a quantitative approach was also used, because it allows the study of a large sample size (Pierce and Stacey, 2010). Hence, surveys and questionnaires were employed to collect data from 15 secondary schools. Forty-five questionnaires were printed; only three teachers from any one school were allowed to participate in study. Consequently, a mixed approach enriched our understanding of the effectiveness of ETAs.

Population and Sample Size

The targeted population was Saudi secondary school teachers, principal stakeholders in the Ministry of Education, and the Technology Implementation taskforce. Heads of mathematics departments were preferred from secondary schools, particularly those who use ETAs in their teaching. A quantitative approach was used to gather data from the teachers. All 45 teachers were given questionnaires with both open- and closed-ended questions. Three stakeholders from the Ministry of Education were interviewed to give their opinions on the progress of the program, the challenges experienced, the measures put in place to enhance the attainment of learning objectives, and their expectations. Additionally, two officers from the Saudi Technology Implementation Department were interviewed, helping us to gather comprehensive information using different sources. Moreover, the inquiries facilitated the collection of data regarding our research questions. All interviews were grounded in a qualitative approach. Because of the sequential design of the study, nested samples were used (Pierce and Stacey, 2010).The sample size was relatively large to enable the attainment of saturated data. Hence, 15 secondary schools in Saudi Arabia were selected with a total of 45 teachers from mathematics departments participating in the research. These individuals participated in the study after being sent a consent letter from the institutional review board stating that the use of the findings would be restricted to academic purposes.

Sampling Methods

The study adopted cluster and systematic random sampling methods. The schools were initially selected using the cluster method, which was preferred because most schools in Saudi Arabia are dispersed over a large geographical area (Creswell, 2014). Participants from the Ministry of Education and the Technology Implementation Department were accorded an equal chance of being selected, and two members from each department were interviewed.

Data Collection Techniques

Information was gathered based on the following questions. Does the use of ETAs improve mathematics learning in secondary schools? Has the Saudi government adequately played its role of facilitating the implementation of the ETA program? What are impacts of ETAs on teachers and learners in secondary schools? What measures can the Saudi government take to enhance the effective implementation of ETAs in secondary schools? Describe obstacles secondary school heads and the government encounter in ensuring ETA implementation succeeds. These were the major questions posed in interviews and questionnaires, which were open for respondents to give their views. Closed-ended questions only examined respondents' understanding of ETAs, their personal information, and their work experiences, which were unimportant for the study.

Secondary school teachers were given questionnaires, whereas stakeholders from the Ministry of Education and the Department of Technology Implementation were interviewed. All 45 secondary school teachers responded to the questionnaires. An official confirmation was obtained from the Saudi Arabian Ministry of Education and the Department of Technology Implementation to help schedule the interviews (Pierce and Stacey, 2010). Potential participants from the departments received official invitations and were informed of the research questions in advance to enhance the disclosure of the relevant information. Respondents further used the opportunity to review the achievements and challenges their respective departments had experienced (Creswell, 2014).

Data Analysis Techniques

Since the study was a mixed sequential study, structured interviews and completed questionnaires were analyzed using quantitative and qualitative methods. Content analysis of the qualitative data involved the following processes: de-contextualization, which involved identifying meaning units, re-contextualization, which encompassed comparing the data, categorization by condensing meaning units to bring subjects together, and finally, compilation to find the underlying meanings of the text. All 45 participants generated quantitative data that were analyzed using content analysis. Raw data were coded before being subjected to the same analytical procedure (Creswell, 2014).

RESULTS AND DISCUSSION

Does the Use of Educational Technology Applications Improve Mathematics Learning in Secondary Schools?

Quantitative techniques were used to gather and analyze data concerning this question. 40out of 45 teachers stated that upon effective implementation, monitoring, and evaluation, the program would probably help the government of Saudi Arabia to attain its overall objective of integrating technology in all disciplines at the secondary level. 78%of respondents stated that the ETA program improves students' mathematical operations and problem-solving techniques. This observation accords with that of Bokhove and Drijvers (2010), who assert that ETAs in mathematics education positively contribute to students' learning outcomes. In this study, ETAs improved students' performance by 10%. Most respondents anticipate that the performance will improve by a further 15% over the next five years. However, they explicitly stated that the increase is substantially determined by teachers', parents', and students' overwhelming efforts. Curiosity among the students increased their thirst to gain a comprehensive understanding of how to solve mathematical problems using these applications. The introduction of ETAs was intended to influence students' perceptions of the subject.

However, 77%of the respondents stated that the government has not fully performed its role of ensuring the program improves mathematics learning in secondary schools. It was evident that Saudi Arabia's Ministry of Education legislates appropriate policies, but lacks the precise mechanisms to facilitate their implementation. In response to whether the government had achieved its projection about the implementation of ETAs in learning mathematics, 96%of teachers, three stakeholders, and two ETA implementation officers stated, "it has not." The findings grounded in both qualitative and quantitative analysis showed that most of the initial plans had been realized, though visions of attaining over 20% improvement in the use of the system in secondary schools across Saudi Arabia required more funding. Financial constraint is a major hindrance to the implementation of ETAs. The argument was that finance is required for the training and recruitment of more teachers who can appropriately use ETAs in teaching mathematics (Clements et al., 2013). Lastly, stakeholders

and technological implementers stated that the program had not yet hit its projected targets; however, it is progressing well.

These findings concur with those of Bokhove and Drijvers (2010), who conclude that the computer algebra system (CAS) significantly improves mathematics education. It is one among many studies that provide evidence of the benefits of incorporating technology into the teaching of mathematics. Saudi Arabia should use such scholarly contributions to actualize objectives from the program and achieve aims that have yet to be attained (Cheung and Slavin, 2013). Undoubtedly, the adoption of ETAs significantly improves mathematics learning in secondary schools. However, the following issues need to be understood: the type of software and applications that are appropriate for secondary schools in alignment with their level of technological integration, and the amount of funding that should be given in support of the program (Clark-Wilson, 2010). Such elements should be assessed and determined by the responsible parties.

Determining the Impact of Educational Technology Applications on Learners

The question of why schools should apply ETAs in teaching mathematics in secondary schools was posed and received different responses. Data for this question were collected and analyzed using qualitative techniques. It was posed to three stakeholders in the Ministry of Education and two members of the ETA implementation team. Four respondents (80%) claimed that technology is currently required everywhere, and incorporating it into mathematics education will equip learners with the latest knowledge on how to handle volatile challenges in society. The study concurred with Cheung and Slavin's (2011) conclusion that incorporating technology in mathematics encourages active student participation and knowledge sharing, creates passive listening, and increases problem-solving skills. Benefits that the respondents highlighted include: enhancing students' focus on the importance of computations, placing emphasis on students' thinking processes, and making ideas tangible. Some applications and software such as Matlab, Microsoft Excel spreadsheets, and dynamic graphing tools were highlighted.

One of the respondents (20%) was not confident that ETAs had positively impacted students' mathematics education. He was of the opinion that the program only influenced those who already had a positive experience of mathematics. He considered the entire initiative to be currently ineffective because it lacks a proper foundation. He suggested that the government should introduce ETAs right away, from primary schools onwards, to help familiarize learners with the applications. He stated that the use of ETAs aims to help teachers to build upon students' skills and knowledge, connect abstractions to real world situations, and link mathematical concepts to increase students' understanding.

Steps the Saudi Arabian Government Has Taken in Support of Educational Technology Applications in Secondary School Mathematics Education

This question was posed to all groups; hence, data were analyzed using both qualitative and quantitative approaches. 80% of the teachers stated that the government had failed to supply the necessary effort to boost the performance of mathematics in secondary schools. Referring to the ICT adoption process, which experienced many problems, they concluded that the adoption of the system in secondary school mathematics classrooms would be similar. 10% claimed that the government had achieved its initial plans for the program. 90% of the teachers stated that they endured many problems in the traditional system, while the other 10% stated that such challenges were inevitable. Hence, they were optimistic the program would yield the projected benefits to learners sooner.

Stakeholders stated that through the Ministry of Education, the Saudi Arabian government had formulated ICT policies to guide the entire implementation process. However, they declined to comment clearly on the effectiveness of the policies. They claimed that the current regulations are unclear on who should execute particular responsibilities. The study revealed that headmasters are given absolute responsibility for facilitating the implementation of ETAs, rather than involving heads of mathematics departments. Also, the government has initiated teacher training programs to help them guide students in the use technology applications for computing mathematical problems. The ETA implementation team claimed that ETAs are ineffective, because about 70% of teachers lack knowledge about how to use the technology, which is a major obstacle to implementation. It emerged that the government has failed to provide maintenance and technical support for when these technologies fail, and that the devices supplied by the government are insufficient to enhance the efficient use of ETAs in secondary schools.

Steps the Saudi Arabian Government Can Take to Improve the Use of Educational Technology Applications in Secondary School Mathematics Education

Data collected were subjected to content analysis, and 80% of respondents felt that the government needed to improve the implementation of ETAs. The remaining 20% were uncertain of what the government should undertake, but they expressed the need for improvement in the

implementation of ETAs. Teachers suggested that the government should establish progressive evaluation and provide pedagogical training, which would positively impact their attitudes and confidence. Stakeholders were of the opinion that the government should provide technological support for the system and craft appropriate ETA implementation policies. The ETA implementation team suggested that the government should provide adequate funding and supportive resources. The study revealed that the program of embracing the use of ETAs in mathematics education in Saudi Arabian secondary schools remains ineffective.

CONCLUSION

Conclusively, Saudi Arabia still has a lot measures to take to ensure that educational technology applications are effectively incorporated into mathematics education in secondary schools. However, the program has a promising potential to impact the performance of students, teachers' attitudes, and overall ministry educational objectives. This study acknowledges the role of the government in ensuring the entire program succeeds. Some of the obstacles that impede smooth implementation of ETAs across Saudi Arabia include: inadequate financial support, lack of well-trained teachers, unclear government policies, and insufficient technical support. Notably, most of these challenges can be overcome if the collaboration among the stakeholders is improved and every party commits to ensuring roles are adequately performed. Achieving efficiency will require the government to improve the current measures and further embrace the others that have been highlighted in this study. Therefore, the initiative of adopting ETAs in secondary schools currently needs improvement in order to be effective.

However, in the process of this study I experienced various obstacles, which can be avoided in future studies. First, it was hard to locate scholarly writing about the use of ETAs in mathematics education in Saudi Arabia. Despite it being generally acknowledged that technology is important in all spheres and that schools should embrace it in teaching mathematics, arts, and science disciplines, few scholars have taken the initiative to research how these technologies can be applied. More studies are required on this topic to explain clearly how the Saudi Arabian government can capitalize on technological advances to improve the teaching of mathematics.

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