

Do Technology-based Approaches Reduce Mathematics Anxiety? A Systematic Literature Review.

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Abstract: The student's attitude towards Mathematics and their achievement is affected by Mathematics anxiety. Mathematics anxiety may lead to avoidance of Mathematics or poor performance in Mathematics and subjects related to or depending on Mathematics. For students to perform well in Mathematics, Mathematics anxiety must be reduced in students. This systematic literature review examines the impact of technology-based approaches on Mathematics anxiety. The strategy used to perform the search for this study consisted of both a discipline-specific journal search and a database search where generalised results about the positive effect of technology-based approaches and their disadvantages were found. 35 papers published between 2002 and 2022 were included in the study and only peer-reviewed articles were included in the search. The study found that using technology-based approaches to teaching Mathematics leads to students showing a positive attitude toward the subject and reduces the level of their anxiety. And when students are confronted with any problem while using technology, in resolving the problem the students develop problem-solving and, in the process, develop their confidence in Mathematics. This study suggests that when incorporating technology into the Mathematics classroom, it is crucial to identify which learning activities benefit the most from technology as some parts of Mathematics may still be best mediated through traditional teaching approaches, such as encouraging class discussion about how to apply mathematical ideas, correcting exercises involving complicated calculations or drawings, and spotting simple arithmetic errors when solving mathematical problems.

Keywords: Technology-based approaches, Mathematics anxiety, Computer-mediated learning, Mathematics teaching method, Solving mathematical problems

I. INTRODUCTION

Mathematics is important in our everyday life, it is used in both formal and informal education (Atoyebi & Atoyebi, 2022). Mathematics is one of the essential subjects for success in academic fields spanning Science, Technology, and Economics. The student's attitude towards Mathematics and their achievement is affected by Mathematics anxiety (Hembree, 1990). Mathematics anxiety is a real problem faced by students (Hlalele, 2012). The working memory of students has been hindered by Mathematics anxiety (Perina, 2002). According to Hill, Mammarella, Devine, Caviola, Passolunghi and Szucs (2016), Mathematics anxiety is "a crippling

negative emotional response to Mathematics". When students react emotionally irrationally when they are expected or compelled to answer mathematical questions, some of them develop Mathematics anxiety (Cobb, et al., 1992).

According to Lyons and Beylock (2012), symptoms of anxiety related to Mathematics are similar to those of other types of anxiety. In individuals with Mathematics anxiety, especially in subjects with severe Mathematics anxiety, the posterior insula, a region of the brain that feels pain in the body, becomes activated. Additionally, as one's academic level rises, anxiety levels also rise (Jackson & Leffingwell, 1999). The difficulty of the content causes a higher level of Mathematics anxiety. Mathematics anxiety in students is shown in their unusual nervousness when in math class, and unwillingness to attempt math classwork and assignment (Mutodi & Ngirande, 2014). Mathematics anxiety may lead to avoidance of Mathematics or poor performance in Mathematics and subjects related to Mathematics. Arem (2003) equated Mathematics anxiety with test anxiety and affirmed that it is three-fold: psychological pressures, poor test preparation, and poor test-taking strategies.

Mathematics Anxiety may cause prospective Mathematics teachers to avoid engaging in any activities that would further their area of expertise and remain inactive in their efforts to become competent. The emotional, cognitive, and physiological aspects of such anxiety can be studied. According to Olaniyan and Salman (2015), students who struggle with Mathematics Anxiety are more likely to conclude that the subject is challenging, dislike it, put off doing their homework, and even skip class. They may perform worse in their math examinations as a result. Choppin (2011) noted that math teachers who struggle with anxiety frequently use textbook-based instruction that places a strong emphasis on fundamentals and few discussion opportunities. Additionally, they are less adept at using different teaching methods for Mathematics in the classroom and do not want to try technology-based teaching methods (Swars, Daane, & Giesen, 2007). The correlation between students' performance (learning outcomes) and Mathematics anxiety was confirmed by Alzaber and Amelia (2014).

Researchers have been inspired to create digital systems and materials for math courses as a result of the development and use of computers and multimedia technologies. Morales (2005) showed that putting Mathematics courses online helped students acquire the material on their own and cut down on the amount of time they needed for remedial teaching. As stated by Damian and Duguid (2004), students' understanding of Mathematics and their ability to apply it to their daily lives could be aided by the use of technology. Nguyen et al. (2006) further stated that interactive and responsive technology-based approach methods could support students in building knowledge. Web-based learning enabled students to improve their mathematical learning attitude and encourages their learning motivation (Steen et al. 2006; Moyer et al. 2008).

Technology has a significant potential to improve learning, understanding, and knowledge retention for students (Hashmi et al., 2019). The Next Generation, which is distinct in that they are the first to have grown up with cyber and digital technologies, learns differently from their predecessors (Barnes, Mateo, and Ferris, 2007). They have teachers outside of school that use technology as a method for teaching, enabling the students to communicate with the teacher effortlessly. Raja and Nagasubramani (2018) further stated that students and teachers may positively benefit from technology and get rid of the constraints that prevent many students and schools from reaching academic success which is anxiety.

On the other hand, Hennessy et al. (2007) suggested that interactive information technology teaching methods could enable teachers to reflect on and enhance curriculum design as well as foster students' capacity for independent thought and problem-solving. Jewitt et al. (2007) affirmed that technological conversations between students and teachers made the curriculum to be more in line with students' ideas and further enhanced the quality of their learning. It appears that technology-supported interactions and learning can foster students' development of mathematical knowledge and improve their drive to learn.

Although previous research has shown that technology can increase students' learning interests in Mathematics and motivations, the effects of technology-enhanced teaching methods on students' anxiety and confidence in their ability to learn Mathematics have rarely been examined. Li et al. (2011) affirmed that it is crucial to take into account students' ability to reduce anxiety in educational environments, particularly in Mathematics classes (Schunk 2007). According to research (Clute, 1984; Bagaka, 2011), students' learning performance in Mathematics and motivation may be strongly impacted by their Mathematics Anxiety. Reducing Mathematics Anxiety could aid students' interest in Mathematics, which could benefit their attitude, and learning efficacy (Peters, 2013). Therefore, it is crucial to suggest new teaching methods or tools related to technology to help students feel more confident and less anxious about Mathematics.

Over time, anxiety in Mathematics has been studied to determine how it can be reduced. Till now, no definitive answer has been provided on how Mathematics anxiety can be reduced even with all of the research that has been conducted on anxiety in Mathematics (Dowker, Sarkar, & Looi, 2016; Ramirez, Shaw, & Maloney, 2018). Pate (2016) examined the current negative effects of implementing technological "applications" for teaching Mathematics which include overdependence on computers which might affect students' concentration span and raises concern about using technology only for convenience and replacement of traditional teaching methods, the propensity of students to adopt a consumer mindset is another negative concern of technology-based approach.

There have been previous studies on Mathematics Anxiety, but they concentrated on the connection between Mathematics Anxiety and math performance (Barroso, Ganley, McGraw, Geer, Hart, and Daucourt 2021; Namkung, Peng, and Lin 2019; Ma, 1999) or the effectiveness of interventions like cognitive behavioural therapy (Bicer, Perihan, and Lee 2020) or cause of anxiety (Atoyebi & Atoyebi, 2022). The meta-analysis on the impact of game-based interventions on student motivation in Mathematics and anxiety is conducted by Fadda, Pellegrini, Vivianet, and Zandonella Callegher (2022), this current paper will examine the impact of the technology-based approach on Mathematics anxiety.

This study is significant because it is not clear how a technology-based approach can reduce Mathematics Anxiety, Glass and Knight (1988) reported a correlation, whereas Todman and Lawrenson did not (1992). The negative impacts of screen use on children in a learning environment cannot be disregarded. Teenage depression and aggressive behaviour are among the consequences of technology (Maras, Flament, Murray, Buchholz, Henderson, Obeid, & Goldfield, 2015); Kim, Cho, and Kim (2017). The use of interactive screens is also associated with ADHD symptoms, suicidal thoughts, and depressive symptoms (Kates, Wu, & Coryn, 2018; Felisoni & Godoi, 2018). Further research is required because it is currently unclear if a technology-based approach entails these concerns (Melo, Madariaga, Nussbaum, Heller, Bennett, Tsai & van Braak, 2020). This study focused on the technology-based approach to reducing Mathematics anxiety.

i. Objectives of the Study

This article is a comprehensive assessment of the literature with the aim of organising and classifying prior research on the impact of technology-based approaches on the reduction of Mathematics anxiety. This paper will identify the gaps in the present body of knowledge, highlights the implications and draws conclusions based on the systematic literature review of selected studies. Papers published between 2002 and May 2022 are included in this study.

II. METHODOLOGY

This study used the systematic literature review methodology to examine the impact of the technology-based approach on

Mathematics anxiety. This type of review closely follows a set of scientific methods that explicitly aim to limit systematic error (bias), primarily by attempting to identify, appraise, and synthesize all relevant studies (whichever design) to answer a particular question (or set of questions") (Petticrew & Roberts, 2006). A systematic review is a type of study design that includes the identification of prior studies pertinent to the chosen issue, critical assessment of those studies, and systematic rules-based analysis of all relevant studies (Millar, 2004; Littell, Corcoran & Pillai, 2008 and Torgerson, 2003). According to Millar (2004), the steps that must be followed in a systematic literature review are: a) setting the objective; b) choosing the studies that are congruent with the aim of the study based on specific criteria; and c) making conclusions from the information acquired. All of these stages are taken into consideration in this study, and the process is carried out by them. Education Research Complete, Google Scholar, Web of Science, and ERIC databases were used in this study. We looked for articles whose title, abstract, or keywords contained both the terms "Mathematics anxiety" and "technology-based approach".

I. Inclusion/exclusion criteria

To define the parameters of this study, a set of exclusion/inclusion criteria was created (Petticrew & Roberts, 2006).

1. Subject matter: Regardless of the academic level, the articles that were included in this study were related to Mathematics anxiety and technology-based approach.
2. Source: This study excluded book chapters and conference proceedings because they do not usually go through a peer review procedure. The quality of the articles chosen was gauged indirectly by restricting inclusion to articles published in education journals.
3. Timeframe: The articles published between 2006 and 2020 were included in this study.
4. Research techniques: This study focused on articles that presented empirical data derived from qualitative, quantitative, or mixed techniques.
5. Language: Papers had to be published in English due to practical considerations.

II. Identification of papers

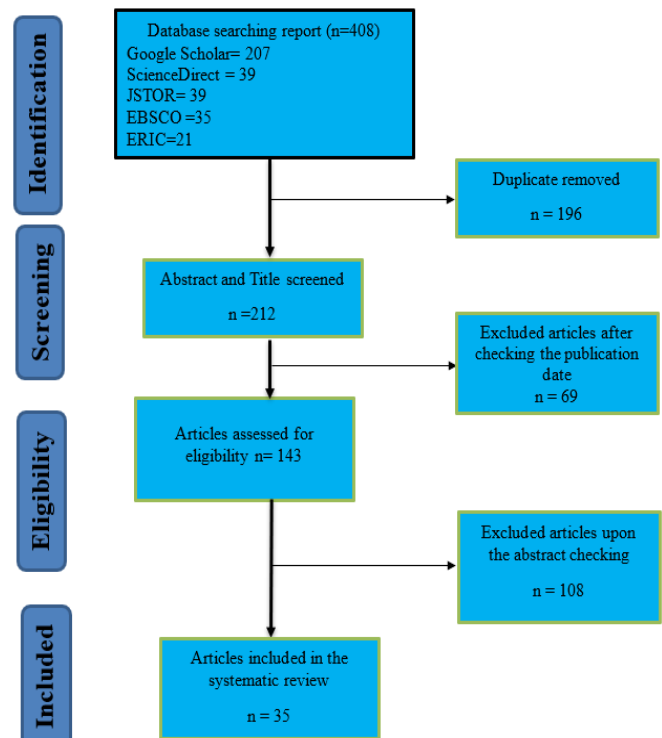
This study adhered to a modified version of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria (Moher et al., 2009). According to the guidelines for a systematic review and by the study's objectives, 408 studies from the years 2006 and 2020 were principally downloaded. These studies were acquired from databases like Education Research Complete, Google Scholar, Web of Science, and ERIC. The keywords "Mathematics anxiety", "technology-based approach", and "computer-based strategies" were used to find publications using the provided databases.

The important criterion in the selection of publications for this study was that they have a direct connection to "technology-based approach" and "Mathematics anxiety". Although some papers had the term Mathematics anxiety in the title and the keyword section, they were not included in this study process because they did not primarily focus on a technology-based approach and were not appropriate for this study.

III. Summarizing the Evidence

The purpose of this study was to review earlier research on technology-based approaches and Mathematics anxiety, taking into account how technology-based approaches reduces Mathematics anxiety. According to the guidelines for a systematic review and by the study's objectives, 408 papers published between 2002 and 2022 were downloaded from the databases like Education Research Complete, Google Scholar, Web of Science, and ERIC. There were 212 papers in all that were screened after the duplicated articles from the two researchers were eliminated. The papers were evaluated to see if they met the inclusion requirements of being full-text and published in English. Of these articles, 69 articles were excluded after checking the publication date. 125 articles were excluded upon the abstract checking. After a lengthy summary procedure, only 35 papers were included in this evaluation. The selection procedure follows the approach used in the previous systematic literature review (Atoyebi & Atoyebi, 2022). The PRISMA Flow diagram is presented in Figure 1.

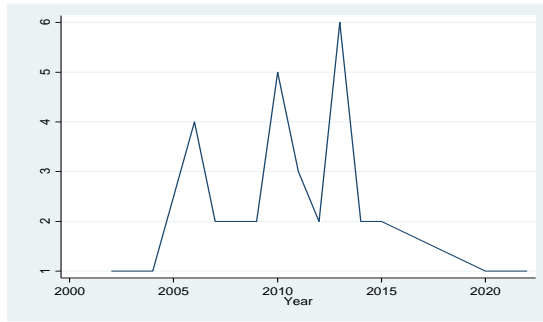
Figure 1: Systematic Search Strategy in Accordance with PRISMA Moher, et al., (2009)



Source: Author's compilation

IV. Distribution of publications

Figure 2: Distribution of publications systematically reviewed.



Source: Author's compilation

The distribution of publications over time is depicted in Figure 1. Distribution of publications that describe the impact of technology-based approaches in reducing Mathematics anxiety. The trend shows that the majority of the work done on the relationship between technology-based approaches and Mathematics anxiety was done in 2013, followed by 2010 and 2006 respectively, there has been a reduction in the number of articles published on the issue since 2014, therefore, this paper will add value to the body of knowledge on the impact of technology-based approaches in reducing Mathematics anxiety.

III. RESULTS AND DISCUSSION

8.57% of the 35 publications reviewed found that Technology does not reduce Mathematics Anxiety. In the study conducted by Istikomah and Sakinah (2013), they found that students are more concerned about not comprehending the concept of Mathematics than using technology, and the use of technology in higher education did not sufficiently reduce students' anxiety about Mathematics. This is consistent with Irfan (2015) finding that students who frequently use technology as a learning tool nevertheless experience significant levels of anxiety when learning Mathematics. The amount of Mathematics anxiety is not considerably influenced by technology (Istikomah & Sakinah, 2013; Irfan, 2015).

91.43% found that technology-based approaches reduce Mathematics anxiety. Appavoo (2020) concluded that the technology-enhanced classes were beneficial for students who were already proficient in Mathematics since they achieved significantly higher grades than their peers in the traditional classes. A further study revealed that, when compared to their peers who studied Mathematics using the traditional approach, students that were taught using the technology approach fared much better in terms of anxiety, and their level of Mathematics anxiety was reduced. The study demonstrated that using technology in lessons was a practical strategy to reduce students' anxiety. According to Jones (2007), technology is regarded to be most effective when the emphasis on learning transfers from the teacher to the student, with the content, pace, and learning activities being determined by the student's interests and abilities. The degree

to which students appreciated their independent learning, working at their own pace, choosing the activities to complete, and receiving immediate feedback for their help the students to reduce their Mathematics anxiety.

Iliyasu (2014) established the positive effects of using computers for teaching to supplement regular instruction including its ability to make students (a) have improved attitudes toward learning, (b) have higher grades on posttests, and (c) learn more in less time. This study also found that using technology has a positive effect on the reduction of the level of anxiety of students, this was also affirmed by other scholars (Kinney, Stottlemeyer, Hatfield, & Robertson, 2004, 2004) that have examined the effect of a computer-based approach on anxiety. Additionally, it was discovered that students benefited from computer-mediated learning when everyone attended class at the same time with the same teacher, creating a sense of community and increasing the likelihood that they would complete the course objectives on time (Kinney & Robertson, 2003).

Tatar, Kağızmanlı, and Zengin, (2015) examined how technology-based approaches and Mathematics anxiety correlated. The respondents of the study were pre-service Mathematics teachers, and the study discovered that pre-service teachers exhibited low levels of anxiety when the technology-related teaching method was used in Mathematics class. The study found that pre-service teachers who felt positively about the use of technology in math courses experienced less anxiety about the subject. Tatar, et al. (2015) concluded that teaching anxiety decreased with favourable perceptions of the "requirements" and "advantages" of using technology, and that teaching anxiety increased with the increasing perception of the "disadvantages" of using the traditional teaching approach. This finding suggests that teachers who believe technology to be beneficial and necessary for teaching and learning have less teaching anxiety than those who believe technology to be harmful. Peker and Halat (2009) found that teachers who used the internet profited from a computer-based learning-teaching strategy and created WebQuest felt less fear when teaching Mathematics and the anxiety level of their students reduced. The conclusion that pre-service Mathematics instructors who had favourable opinions of technology use had less teaching anxiety is consistent with Fadda, et al., (2022) findings. Additionally, Taylor and Galligan (2006) discovered that using technology in Mathematics lessons leads to pupils showing a positive attitude toward the subject because a technology-based approach reduces the level of anxiety of students.

The association between pre-service teachers' computer literacy and anxiety related to teaching Mathematics was also investigated by Sun and Pyzdrowski (2009). The study found that as computer literacy levels of pre-service teachers increased, anxiety related to teaching Mathematics decreased. In an atmosphere where students may develop their knowledge and learn Mathematics collectively using diverse applications, computers, and websites with mathematical information, the anxiety level of students in Mathematics

diminishes (Sun & Pyzdrowski, 2009). Considering the connection between Mathematics anxiety and teaching Mathematics using technology, Peker and Ertekin (2011) found that Mathematics teaching anxiety may decline as computer literacy levels rise, and a reduction in Mathematics teaching anxiety influences the level of students' Mathematics Anxiety.

Strong (2013) affirmed that giving priority to the applications in which technology is used in the teacher training process and supporting these applications with cutting-edge software will contribute significantly to decreasing teaching anxiety. According to the study, pre-service teachers' anxiety related to teaching Mathematics may decrease as their perception levels regarding technology use in Mathematics teaching positively increase and their computer literacy levels increase. According to Alavi et al. (2002) and Cramer et al. (2008), employing multimedia to present learning materials may encourage students to study Mathematics and reduce their Mathematics Anxiety. Information technology-enhanced learning may be a way to increase students' motivation to learn Mathematics (Burguillo 2010). Kuo (2007) reported that digital games may offer a learning environment that sparks children's interest in learning Mathematics, and reduces the level of students' Mathematics Anxiety. Other studies found that a technology-based approach decreases Mathematics Anxiety and increases students' drive to learn Mathematics, which might lead to strong academic performance (Liu and Chu 2010; Houssart and Sams 2008; Dickey 2010; Huang 2010; Sung & Hwang, 2013; Hwang, Sung, Hung, & Huang, 2013).

There might be some problems using technology to teach Mathematics but when confronted with any problem, in resolving the problem the students develop problem-solving and, in the process, develop their confidence and reduces Mathematics anxiety (Hwang, et al. 2013). It is anticipated that by incorporating educational objectives and materials into technology, students' motivation to study will be increased and Mathematics anxiety will reduce due to the teachers' engagement in technology (Hwang et al. 2012). Wang and Chen (2010) demonstrated that the technology-based approach significantly increased students' engagement in programming activities that involve calculations and reduce their anxiety of the students, even though most students find these to be challenging and monotonous. According to Dickey (2011), the technology-based strategy can help students become more intrinsically motivated and reduce students anxiety. Also, Yien et al. (2011) found the beneficial impact of video games on students' academic success. The Hung et al. (2012) study also demonstrated how, with the right design, digital games could enhance students' spatial cognition skills and influence their anxiety levels. According to the research, a technology-based approach may be an effective strategy for raising students' interest in learning Mathematics and reducing their level of anxiety.

Hung, Huang, and Hwang (2014) created a technology-based environment for mathematics classes to examine how

Mathematics Anxiety is influenced by a technology-based approach. The children in the study used e-books with wireless connectivity to access the online math games. Comparing the learning accomplishments, self-efficacy, learning motives, and Mathematics Anxiety of the students who learnt using the technology-based approach, and traditional technique. The study found that from the pre-and post-questionnaire evaluations after the learning activity, the Mathematics anxiety ratings of the e-learning group and the digital game-based learning group both reduced, whereas those of the traditional instruction group increased. This suggests that a technology-based approach has a good chance of reducing students' fear of math. In other words, it will be beneficial to create and use digital math games to reduce students' Mathematics Anxiety.

The impact of web-based instruction on Mathematics anxiety was studied by Gundy, Morton, Liu, and Kline (2006) using undergraduate studying statistics at a University in the Northeast United States as a case study. The study revealed how undergraduates deal with Mathematics anxiety and how web-based instruction reduces anxiety in statistics classes. In the same vein, Gundy et al. (2006) also explored how Mathematics anxiety is reduced, and the use of technology decreases Mathematics reduction. In the research conducted by Gundy et al. (2006), it found that Mathematics anxiety was reduced from Time I (beginning) to Time II (the end) of the course instruction periods when the web-based instruction method was adopted. The study also found that participation of students in online discussion forums is encouraging, which shows that the self-esteem levels of the students improved. Yushau (2006) examined the impact of web-based learning on Mathematics anxiety. The study found that Mathematics anxiety in students is not reduced by using any web-based tools.

IV. CONCLUSION

This study conducted a systematic literature review of the empirical research on the efficacy of a technology-based approach to reducing students' levels of Mathematics anxiety. According to the literature review on the impact of technology-based approaches on the reduction in Mathematics anxiety, Mathematics anxiety reduces when technology-based approaches are used in Mathematics classes. Six of the thirty-one studies that were analysed were published during the last four years. Overall, based on information from different categories of education, such as primary, secondary, and tertiary education, researchers have undertaken empirical studies in different countries and geographical regions. The various technology-based approaches reviewed were; the use of computers for teaching, technology-enhanced classes, computer-based approach, technology-based approaches, computer-mediated learning, computer-based learning-teaching strategy, multimedia, web-based learning, information technology-enhanced, digital games, video games, technology-based environment, and web-based instruction. 35 studies satisfied the selection criteria describing how technology-based approach influence

Mathematics Anxiety. Many students experience Mathematics anxiety, hatred, and fear which makes learning a miserable experience. The effect of Mathematics anxiety on students extends to Mathematics teachers; when students find it difficult to understand Mathematics because of anxiety, it leads to Mathematics teachers' burnout. This study concluded that technology can help in reducing Mathematics anxiety and create a passion for Mathematics if used properly. According to research (Erbaş & Aydoan Yenmez, 2011; Berger, 2010; Lagrange, 1999; Güven & Karataş, 2003; Wong, Yin, Yang, & Cheng, 2011; Marshall, Buteau, Jarvis, & Lavicza, 2012), the use of technology in Mathematics teaching method has a favourable impact on students' and teachers' anxiety levels. The results of this study show that every child that is experiencing Mathematics Anxiety can benefit from a technology-enhanced approach. However, steps must be taken to prevent the emergence of a second digital divide, this calls for equipping students experiencing Mathematics Anxiety with the fundamental knowledge of technology and abilities required to avoid adding to their cognitive load when learning new ideas. When incorporating technology into the classroom, it is crucial to identify which learning activities benefit the most from technology as some parts of Mathematics may still be best mediated through traditional teaching approaches, such as encouraging class discussion about how to apply mathematical ideas, correcting exercises involving complicated calculations or drawings, and spotting simple arithmetic errors when solving mathematical problems. To ensure a smooth transition away from the traditional manner of teaching, technology must be gradually introduced. Despite their familiarity with the tool, students still need to get used to it as a learning tool. For technology advancements to be used effectively in education, computer literacy and the ability to use the internet are prerequisites for both students and their teachers.

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