Contemporary Educational Technology, 2022, **14**(3), ep364
ISSN: 1309-517X (Online)

OPEN ACCESS

Research Article

Can Electronic Board Increase the Motivation of Students to Study Mathematics?

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Citation: Ben Abu, Y., & Kribushi, R. (2022). Can Electronic Board Increase the Motivation of Students to Study Mathematics?. *Contemporary Educational Technology, 14*(3), ep364. https://doi.org/10.30935/cedtech/11807

ARTICLE INFO

Received: 27 Dec 2021
Published: 16 Feb 2022

ABSTRACT

During the junior high and high school years, there is a dramatic decrease in motivation for math studies, which has been found to play a major role in learning processes. Many attempts have been made to mitigate this decrease in motivation and to encourage mathematics studies in higher grades. One way that researchers have proposed to stimulate students' curiosity and their perceived ability in math is to integrate technology into teaching. Such technology includes technological tools, digital educational activities, learning support software. Using tablet in class has significant potential to improve learning but the issue of how to effectively integrate digital technology into teaching and learning practices becomes critical. According to that knowledge we examined the impact of the use of a digital writing board (similar to tablet) by the lecturer during frontal lectures in mathematics on students' learning motivation in an engineering academic preparatory program, following motivational constructs: self-efficacy, implicit theory of ability, value beliefs, and learning climate. The results showed that the technological tool positively affected two important motivational constructs that influence general motivation for mathematics studies.

Keywords: motivation, teaching using technological tools, digital writing board, teaching mathematics, pre-academic preparatory program

INTRODUCTION

Motivation for Mathematics

In recent decades, studies have shown that motivation plays a major role in learning processes (Kaplan & Decade, 2002); the duration of learning, subject study choices, ways of learning, and learning success are influenced by motivation (Schunk et al., 2008), so motivation is considered the most important component that drives a student to learn (Gee, 2003). Mathematics studies are known to be challenging, and with each subsequent year in school, there is a dramatic decrease in motivation for mathematics studies (Blackwell et al., 2007; Star et al., 2014). This phenomenon conflicts with the finding that middle school is a critical period in which students make decisions about their futures in STEM field and that success in mathematics is particularly important in these years (Adelman, 2006; Star et al., 2014). From a theoretical perspective, intervention studies have helped move the field forward, providing insights into how learning affects motivation (Lazowski & Hulleman, 2015). An example of recent motivational research is a study by Star et al. (2014) that examined a motivational model for mathematics studies based on the essential components that the National Academy of Sciences (2011) argue that should be present among middle school students (Star et al., 2014). The motivational model includes **S**elf-efficacy, **I**mplicit theory of ability, and **V**alue beliefs. Another factor that has not been considered in previous research and that will be examined in this study is learning **C**limate, which is also an integral part of Star's model. These four components are the basis of the motivational SIVC model, which enables the examination of student motivation (Star et al., 2014).

Self-Efficacy (S)

Self-efficacy is defined as "the person's belief in his abilities to organize and carry out a series of actions and thereby help achieve his goals" (Bandura, 1997). An individual's self-efficacy concerns a central question: "Can I do the task?" Self-efficacy can be evaluated according to the following three metrics (presented in order of their importance): (i) *personal experience*, which provides the most reliable assessment of the person's ability to perform a task (Bandura, 1986); (ii) *observation*, which provides the student with an appreciation of his or her behavior in relation to that of his or her peers but has less of an impact on the student's perception of self-efficacy than personal experience (Schunk, 1989); and (iii) *emotional arousal*, which refers to physiological reactions (increased heart rate, sweating, etc.) and emotional responses (anxiety, stress, fatigue, etc.) that can indicate anxiety (Bandura, 1994).

Implicit Theory of Ability (I)

Implicit theory of ability is one of the most common factors used to predict study motivation (Dweck & Leggett, 1988) and plays an important role in an individual's choice of career (Blackwell et al., 2007; Rattan et al., 2012). Implicit theory of inner ability concerns the following question: "Can I improve my ability?" Two mindsets can be distinguished among students in relation to implicit theory of ability (Blackwell et al., 2007; Dweck, 2008): a *fixed theory of ability* in which one's inner ability is perceived as permanent and immutable, or an *incremental theory of ability* in which one's ability is perceived as flexible, acquired, and able to be developed. Numerous studies have shown that a person's belief in his or her abilities has a considerable impact on his or her motivation and achievements (Bandura, 1997; Blackwell et al., 2007; Dweck & Leggett, 1988).

Value Beliefs (V)

Value beliefs are defined as an array of a person's subjective beliefs that influence his or her choice of activity to perform, the duration of the activity, and the ability to persevere to carry it out (Eccles et al., 1983); value beliefs address the question, "Do I want to invest in and continue studying various subjects in mathematics?" This factor was found to be significant in student motivation for studies (Eccles et al., 1983). Value beliefs include (i) *interest value*, which concerns which task will be chosen according to the person's interests, enjoyment, and involvement in that task; (ii) *utility value*, which concerns the viability of investing in a task to achieve the person's future goal; (iii) *attainment value*, which is the degree of success in performing a task affects the student's identity; and (iv) *cost*, which refers to the effort required to perform a task, the feelings associated with the task and its results.

Learning Climate (C)

The learning climate refers to the social, psychological, and pedagogical aspects of the learning environment that affect students' cognitive, motivational, emotional, and behavioral outcomes (Gherasim et al., 2011; Lüdtke et al., 2009); the learning climate concerns the question, "Does the curriculum allow me an opportunity for meaningful learning?" The Ministry of Education defined the learning climate as one of the standards of a supportive culture and optimal school climate (Ciccone & Freibeg, 2013). A positive learning climate enables a meaningful learning environment that supports learning, evaluation, and feedback processes; that strengthens learning for which students might lack internal motivation; and that enhances students' perceived ability to learn and increase their achievements. A positive learning climate can be promoted by creating a diverse learning environment that stimulates interest, strengthens students' perceived abilities, considers diversity in evaluation and feedback processes, and develops and strengthens study styles and methods; that is, the learning climate predicts motivation, thinking processes, performance, behavior, and general access to the profession (Ames & Archer, 1988; Fraser & Tobin, 1991; Gherasim et al., 2011). Given the decline in student motivation for middle and high school math studies (Chao et al., 2016), many researchers have looked for ways to increase students' level of interest in and motivation for math classes; one identified approach was to integrate technology into classes (Star et al., 2014). Therefore, in this study, Star's SIVC motivational model was extended to include another category, i.e., perception of technology in class, and this extended model is referred to as the SIVCT model.

Perception of Technology in Class

In the 1990s, the potential of integrating technology in teaching and learning was increasing (Weigand, 2017), and in recent years, technology has come to be seen as a necessary tool for studying motivation due to the amount of their free time that students spend using technology (Magnifico et al., 2013). As a result, many curricula have been developed, and studies have been carried out showing that integrating and using technology in math teaching can encourage students to become active participants in class (Raines & Clark, 2011). Technology use is also common among students; each student has at least one portable digital tool (a cell phone, tablet, or laptop), and they can use these tools in their learning (Bates, 2018). In recent studies in schools, teachers and students have reported that in lessons with technological tool integration, the levels of enjoyment, understanding, and interest among students increase, as does the level of motivation to participate in the lesson (Chao et al., 2016); recent studies have even shown that the integration of technology in teaching has a positive impact on the SIVC motivational constructs (Chao et al., 2016; Francis, 2017).

Integrating Technology in Teaching

Mathematics lessons have been administered through frontal instruction since the 19th century so that the performance of teaching and educational tasks would be the same for everyone (Brooks & Grennon-Brooks, 1999; Karweit, 1987). Frontal instruction involves the teacher being at the center of the lesson, determining the rate of the lesson and being responsible for what is happening in the classroom; in addition, it involves the student and his or her success being measured based on his or her memorization ability and grades (Elliot & McGregor, 2001). This traditional teaching approach with the curriculum at its center is also referred to as "old education" (Harpaz, 2005). An opposing teaching model developed in the last century was defined as "a new education"; this approach advocated the personal development of the student and the use of emerging content that is shaped by the learner through the use of his or her own internal discipline (Harpaz, 2005). Numerous studies have shown that "active involvement in learning may lead to better memory and understanding and more active use of knowledge" (Perkins, 1999). One of the pedagogical approaches to active involvement and personal experience is the constructivist approach (Perkins, 1999; Phillips, 1995). Constructivist learning techniques require more time than traditional educational practices (Perkins, 1999), but many educational frameworks do not provide this additional time. A solution that employs constructivist teaching and learning perspectives but addresses the issue of the additional time required is teaching according to the pragmatic constructivist approach. According to this approach, knowledge is not particularly problematic; knowledge can be taught according to the traditional approach, but in a subject that students have difficulty understanding, a different approach may be required that is more or less understandable (Perkins, 1999). Based on previous attempts at integrating technology into teaching, research has shown that despite extensive investments in adopting various technologies, the use of technology has not led to a revolution in teaching or learning, and "the effectiveness of using it [technology] to ignite student interest in the academic content is sparse" (Chao et al., 2016). However, knowledge is not the only goal of education, but strategies, meta-cognitive skills and affective aspects are important goals as well (Creemers, 2005).

Digital Tools

A digital drawing board is a technological tool that connects to a computer and serves as a page that can be written on with a specialized pen; a similar alternative is a touchscreen where writing is done directly on the screen (like tablet or laptop with touch screen). It can be used by teachers and students, while maintaining retains essential writing elements, such as handwriting (Galligan et al. 2010; Maclaren, 2014), symbols, abbreviations, graphs, etc.; verbal communication and body gestures (symbols and movements) (Maclaren et al., 2018); digital drawing board best combines traditional teaching methods with technology and addresses the disadvantages of other technologies. For example, the whiteboard could be used but the possibility that every classroom will be equipped with one is slim and it isn't easily portable (Timmins, 2004). This technology has also been shown to support multimodal learning, in other words' the use of different modalities or

Figure 1. Gathering learning in one place. Colorful writing tools–Writing is done with a pencil or marker pen of a selected color and thickness. Digital notebooks–All the information presented in the lesson is written in a notebook in a similar way to writing on a regular board in the classroom. Lessons can be organized according to the field and subject, and users can easily move between lessons; each lesson can be saved as a file. Digital books–The study material and handwritten notes can be accessed anywhere at any time. Distance learning–Distance teaching can be very similar to teaching carried out in the classroom in terms of writing on the board. Tools for drawing and calculating–The various tools allow graphing, copying, and combining sketches in the digital notebook; marking notes; indicating solutions, etc. Course site–Each file can be added to the course site so that the file is available and accessible to students. Social media–WhatsApp is an example of a channel of communication that can be used between students and lecturers; such communication allows solutions to be sent quickly, easily, and conveniently to students. Internet information sources–During a lesson, users can search for examples, sites or videos and use them in a lesson as a link or as an image

combined (e.g., text, sound, video, and pictures). **Figure 1** shows an example of the use of using digital drawing board.

The lecturer writes on the digital drawing board with a dedicated pen, and the written material is projected onto the board using a projector (connected to the computer) so that the lecturer's face can be directed towards the students during the class without the lecturer needing to turn his or her back on the students to write on the board (Maclaren et al., 2018). The lecturer can see the students throughout the lecture and can thus be attentive to the rate at which they are copying material from the board and their extent of understanding, for example, based on their facial expressions. Therefore, the lecturer can respond quickly to questions or provide further explanations of the material being studied and prevent student frustration during the lesson (Galligan et al., 2010). The digital drawing board makes it easy to use the written material in multiple different types of software (Maclaren, 2014) and to save the material and make it available to students. In addition, it enables many students who have difficulty quickly copying the material while also listening to the lecture to better understand the lesson and allows them to replay the lecture from the classroom in their spare time at home; thus, students can interact with the material repeatedly. The ability to make files available to students also encourages independent learning, which is one of the requirements for proper professional functioning, including technical professions (Bates, 2018). Therefore, teaching using a digital writing board allows the lecturer to manage all aspects of learning in one place (Svela et al., 2019) (**Figure 1**).

Motivation for the Research

Despite the diverse and encouraging programs for high-level math that currently are offered in schools, there are many students who have graduated school and lack confidence in their abilities in the field of mathematics and science. Unlike in primary and secondary school, where students are obliged to study mathematics, in college, students who want to study engineering choose to study high-level mathematics, despite their painful experiences of failure, and they seek to "correct" their high school performance (Gero & Abraham, 2016). One way for these students with unfulfilled potential to enter higher education institutions is through a preacademic preparatory program, and without this help, some will not be able to enter higher education. Studies have shown that the tablet has significant potential to improve learning, even though it is used without an established pedagogical background, and yet the most important component of learning is the teachers and their practice in the classroom (Svela et al., 2019).

Research Questions

1. How does frontal instruction using a digital drawing board affect students' self-efficacy, implicit theory of ability, value beliefs, learning climate, and perception of technology in class?
2. How does frontal instruction using a digital drawing board affect students' overall motivation?

METHODOLOGY

This was a quantitative study that used online (pre- and post-) questionnaires as the research tools; statistical analysis of the data was conducted with SPSS. The questionnaires included the original questionnaire used by Star and his colleagues (Star et al., 2014) and a questionnaire from a study conducted to test motivation among students before and after a technology intervention (Fogarty et al., 2001). The two questionnaires were grouped together for the pre- and post-questionnaires and examined the five SIVCT motivational constructs using 50 statements. Of the 207 students enrolled in courses in the preacademic preparatory program for engineering, 178 students answered the pre-questionnaire, 75 of whom were from the intervention group (42%), and 140 students answered the post-questionnaire, 59 of whom were from the intervention group (42%). Of the respondents, 89.6%were men, and 10.4% were women. Among all the student, 89.3% were born in Israel.

FINDINGS

The findings of the study will be presented according to the changes that occurred within the groups and the differences between the groups.

Changes from Pretest to Posttest in Each Group

The students from the intervention group showed a definite increase in their scores from the pre- to post-questionnaires for the motivational components learning climate, $t(132)=-4.47$, $p<0.01$, and perception of technology in class, $t(105.58)=-3.51$, $p<0.01$. On the other hand, the other motivational components, i.e., self-efficacy, implicit theory of ability and value beliefs, did not increase, $p>0.05$. In addition, overall motivation showed a definite increase, $t(132)=-1.94$, $p<0.05$, as shown in **Figure 2**. **Figure 2** shows the changes in the scores of each construct from the pre- to post-questionnaires in the intervention group. It shows that there was almost no change in the scores of the self-efficacy and value beliefs constructs. The score of the implicit theory of ability construct decreased. For the scores of the learning climate and perception of technology in class constructs, there was a significant increase between the questionnaires.

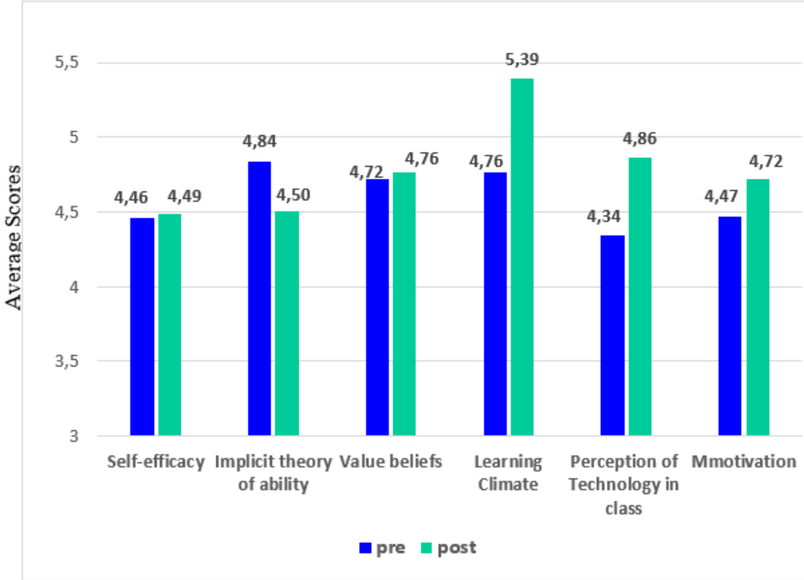

Figure 2. Average scores on the pre- and post- questionnaires in the intervention group by SIVCT construct and general motivation

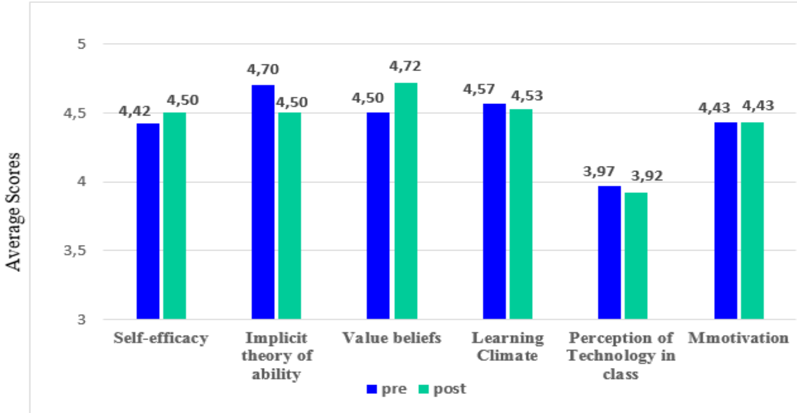

Figure 3. Average scores on the pre- and post-questionnaires in the control group by SIVCT construct and general motivation

In the control group, the students' scores showed no definite change (p>0.05) in any motivational construct between the pre- and post-questionnaires, as shown in **Figure 3**. **Figure 3** shows the differences in the scores for each construct between the pre- and post-questionnaires in the intervention group. It shows almost no change in the scores for self-efficacy, learning climate, and perception of technology in class constructs and general motivation. The score for the implicit theory of ability construct decreased, and the score for the value beliefs construct increased, but not significantly.

Comparison of the Intervention Group with the Control Group

There was no difference between the two groups in the score for the self-efficacy motivational construct on the pre-questionnaire (t(176)=0.33, p=0.75) or the post-questionnaire (t(138)=-0.38, p=0.97), as shown in **Figure 4**. **Figure 4** shows a slight difference between the groups on the pre-questionnaire and a slight increase in both on the post-questionnaire. There was no significant difference between the groups.

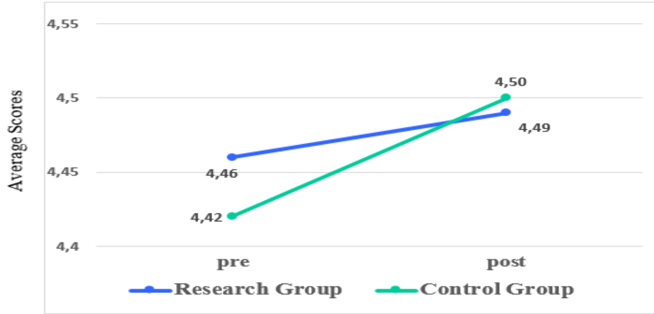

Figure 4. Average self-efficacy scores on each questionnaire in each group

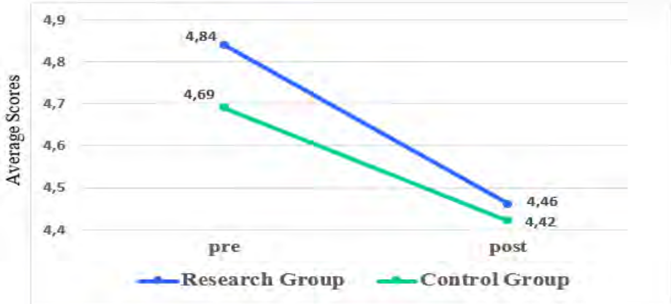

Figure 5. Average implicit theory of ability scores on each questionnaire in each group

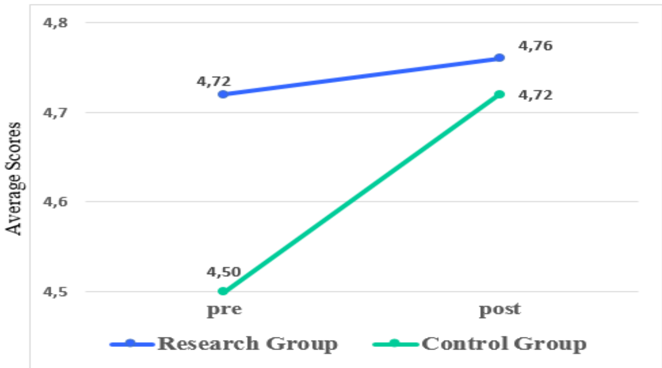

Figure 6. Average value beliefs score on each questionnaire in each group

There was no difference between the groups in the score for implicit theory of ability on either the pre-questionnaire, t(176)=0.97, p=0.75, or the post-questionnaire, t(138)=0.04, p=0.97, as shown in **Figure 5**. It shows a slight difference between groups on pre-questionnaire and a decrease in both groups on the post-questionnaire.

For the motivational construct value beliefs, the students from the intervention group had distinctly higher scores than the control group on the pre-questionnaire, t(175.86)=2.06, p=0.04, but there was no difference between groups on the post-questionnaire, t(137.54)=0.33, p=0.74, as shown in **Figure 6**. **Figure 6** shows a definite difference between the groups on the pre-questionnaire and an increase in both groups on the post-questionnaire, with a decreased difference between groups on the post-questionnaire.

For the learning climate motivational construct, there was no difference in the scores between the two groups (176)=1.34, p=0.18 (intervention group, M=4.76, SD=0.83; control group, M=4.57, SD=1.04). However, a definite difference was found between the groups on the post-questionnaire, t(126.34)=4.44, p<0.001 (intervention group, M=5.39, SD=0.77; control group, M=4.53, SD=1.48), as shown in **Figure 7**. **Figure 7** shows a slight difference between the groups on the pre-questionnaire and a definite difference on the post-questionnaire.

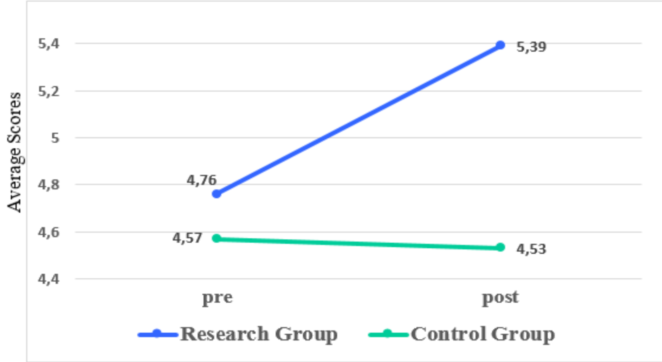

Figure 7. Average learning climate score on each questionnaire in each group

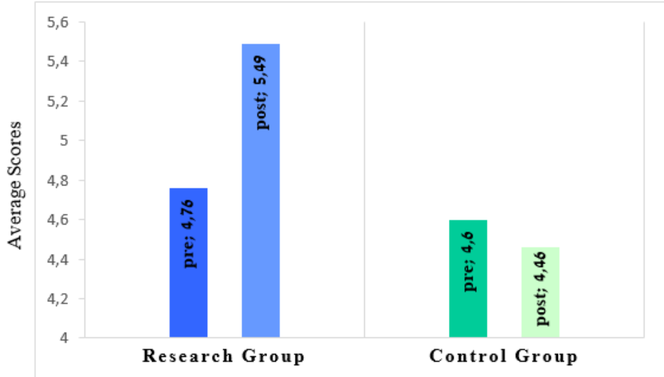

Figure 8. The average learning climate score on each questionnaire in each group for the following question: The math lecturer tries to understand how I see things before suggesting another way to do it

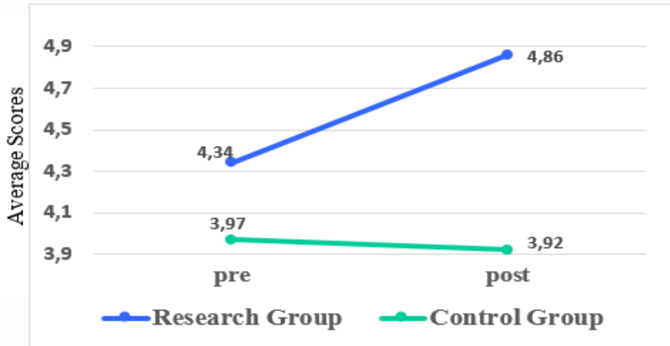

Figure 9. Average technology in class scores on each questionnaire in each group

An example from a question for the learning climate motivational construct is shown in **Figure 8**. This finding shows that in the intervention group, there was a dramatic increase in the score, while in the control group, there was a slight decrease.

For the motivational construct perception of technology in class, the students in the intervention group had significantly higher scores than the students in the control group, $t(176)=3.25$, $p=0.001$, on the pre-questionnaire as well as on the post-questionnaire, $t(138)=6.11$, $p< 0.001$, as shown in **Figure 9**. **Figure 9** shows a definite difference between the groups on the pre-questionnaire and an even larger difference between the groups on the post-questionnaire.

An example for a question for the motivational construct perception of technology in class is shown in **Figure 10**. This finding shows that in the intervention group, there was a dramatic increase in the score, while in the control group, there was no change.

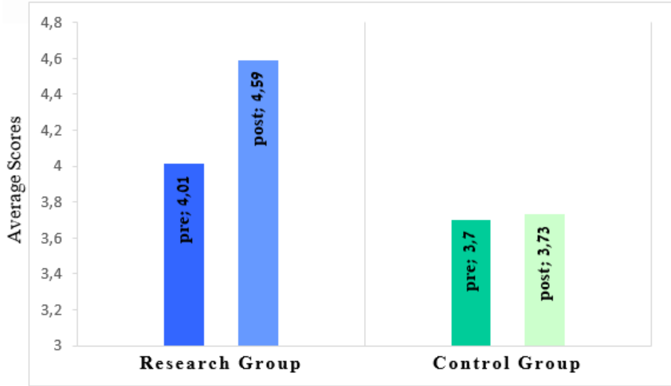

Figure 10. The average perception of technology in class score one ach questionnaire in each group for the question: How much I love the idea that mathematical methods and ideas can be explored using technology

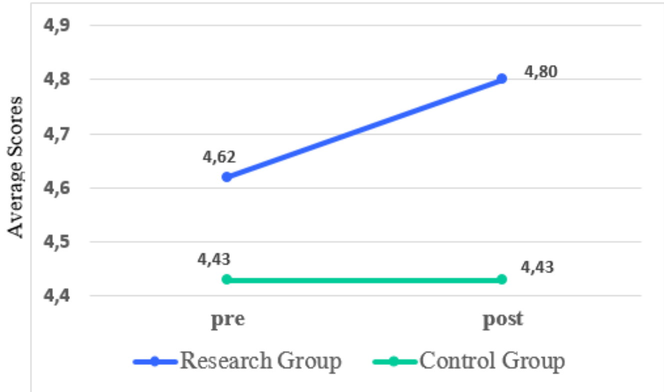

Figure 11. Average general motivation score on each questionnaire in each group

For general motivation, the students' in the intervention group had distinctly higher scores than the control group on the pre-questionnaire, t(176)=2.22, p=0.03, as well as the post-questionnaire, t(137.88)=3.46, p=0.001, as shown in **Figure 11**. **Figure 11** shows a definite difference between the groups on the pre-questionnaire and an even larger difference on the post-questionnaire.

SUMMARY AND DISCUSSION

The purpose of this study was to examine the motivational effect of the use of a digital writing board on students during math classes using the expanded SIVCT motivational model. The findings indicate that the learning climate and perception of technology in class motivational constructs and general motivation increased significantly from the pre-questionnaire to the post-questionnaire. For the learning climate motivational construct (C) on the pre-questionnaire, no difference was found between the groups. However, there was a definite increase in the scores for this construct for the intervention group, as shown in **Figure 7**. The use of digital board has been led to a meaningful learning environment, relaxed learning atmosphere and maximize student learning abilities. The study findings are consistent with the findings of various studies conducted in the field with the use of technology in math classes, which was found to affect the learning climate and predict motivation and attitude towards math in general according to students' subjective conceptions (Ames & Archer, 1988; Fraser & Tobin, 1991; Gherasim et al., 2011). In other words, the use of digital board affects the learning climate.

For the motivational construct perception of technology in class (T), there was a definite difference between the intervention group and the control group on the pre-questionnaire, and this difference increased on the post-questionnaire, as shown in **Figure 9**. Using the digital board increase the levels of enjoyment understanding and interest among students (it was easy to combine other technology tools like Desmos or recording the lessons) as does the level of motivation to participate in the lesson, student can ask freely about a topic previously studied and the lecturer can move easily between lessons and close the resulting gap. Studies have found that students are more satisfied in classrooms with innovative teaching methods (Moos, 1976). One way to use innovative teaching methods is by integrating technological tools, such as the technological tool used in the study, into the learning process (Star et al., 2014). Studies on the integration of technology into teaching refer to innovation as a factor that increases the levels of interest, enjoyment, and creative teaching and focuses students' attention and attention on activity (Serin, 2015; Serin & Oz, 2017).

According to these findings, the proper use of technology by teachers increases the level of motivation for learning in all fields of study, including mathematics (Bakar et al., 2010; Francis, 2017). The existing literature on the impact of teaching with technology on motivation for learning has been inconclusive (Moos & Marroquin, 2010). Some studies showed that students learning outcomes were not improved when using tablets (Svela et al., 2019). On the other hand, some studies have shown that use of technology (such as tablets or smart phones) in math classes positively affects students' achievements, motivation, attitudes and cognitive skills (Tingir et al., 2017). Unlike studies in which students have experimented with technological tools within a school framework, this study involved the use of technological tool by the lecturer who expert using that technology. Therefore, it was expected that students would not change their perceptions of the use of technological tools in the lesson or would change their minds only slightly because they did not use it by themselves; however, there was a large difference between the intervention group and the control group at the beginning of the study. The students in the intervention group had already been exposed to the digital writing board for two to three weeks before they completed the pre-questionnaire. Thus, it is possible that the effect of the intervention and changes in their perceptions of technology in class may have already begun at the time of the pre-questionnaire, hence the gap between the two groups.

Understanding the relationship between the use of digital board and its impact on motivation for learning math is important, mainly due to the decrease in motivation for math studies in recent years. The results of the study encourage the development of a teaching program using this technological tool while training teachers to expand its impact on the other motivational constructs and to research which specific features of the digital learning board, most enhance the learning experience. Another recommendation for follow-up research is to expand the use of technological tools even among students (Chao et al., 2016) to enable their greater involvement in all learning processes, such as by actively building their knowledge, supporting their research and discovery, and encouraging their meaningful learning as they learn learning through various interactions.

Notably, despite the enormous potential that technology has, its improper use can impair teaching and motivation for learning and may also impair the adoption of follow-up technology (Billman et al., 2018; Bransford et al., 2000). Therefore, to integrate technological tools into lessons, the lecturer must adopt innovative pedagogical technology and must develop new skills and adapt the teaching method to the new learning environment. It is possible that the proper integration of tools in class by teachers will increase their motivation for teaching, which will also lead to an increase in student motivation.

Regarding the effect of the technological tool on students' general motivation for studying mathematics, a definite difference was observed between the groups on both the pre- and post-questionnaires, as shown in **Figure 11**, which is contrast to Star et al.'s (2014) report of a small increase in motivation in his research. Motivation plays an important role in influencing student learning and achievement (Liu et al., 2011), and therefore, it is important to understand what criteria affect it. Since the questionnaires were administered between two and three weeks after the start of the semester, and since the students in the intervention group had already begun studying with the technological tool during these three weeks, it is possible that during this period of time, there had already been a change in student's perception of the use of the tool in the class and that the use of the tool had already had an effect on their general motivation for studying the mathematics profession. In addition, more than half of the students were born after 1995, and they are thus are defined as generation Z, i.e., "digital natives". Generation Z is the first generation for which technology has been accessible from an early age, and members of this generation use many apps simultaneously (Cilliers, 2017; Wallace-Spurgin, 2019). In addition, generation Z is characterized by visual learning ability and experiential practice (Rothman, 2016; Wallace-Spurgin, 2019), and members of this generation enjoy learning according to their skills (Bates, 2018).

Furthermore, the COVID-19 epidemic has led many governments to declare the need to maintain safe distances between people and to close educational institutions (Reimes et al., 2020). Schools, universities and colleges have had to switch to remote teaching and use digital teaching and learning tools to avoid interrupting the curriculum, allow students to graduate and prevent students from dropping out of school as much as possible. Skills for teaching and learning with digital tools instantly became necessary for all teaching staff and students in schools and academia. The digital tool examined in this study can be used to address the difficulties created as a result of the transition to remote learning due to the COVID-19 epidemic. Therefore, the effective integration of technology in teaching requires the proper management of diverse technology so that the lecturer can choose an appropriate technology to use during the lesson that will help transfer knowledge or help students create knowledge in the clearest and most interesting way. Technology should be integrated in the classroom and be as accessible as any other educational tool.

Author contributions: All authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. All authors approve final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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