Learning Design of Quadratic Equation Using ICT to Understand the Concept and Reduce Math Anxiety

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Abstract
Quadratic equations are essential material that students need to master. Based on several studies, many students have not mastered the material because they have not mastered the prerequisite skills and find solutions. This study aims to describe the learning design of quadratic equations using ICT, namely the Algebra Tile app, to understand the concept and reduce students' math anxiety regarding Cone of Experience Theory, Information Processing Theory, and Genesis Instrumentation Theory. The material is limited to quadratic equations with rational roots. The design of learning quadratic equations using ICT refers to three stages of development, namely: (1) analysis stage, (2) design stage, and (3) development stage. The results showed that the learning design was valid, practical, and effective. Using algebraic tile applets helped students factor in quadratic equations and lowered their anxiety during learning. Furthermore, the efforts made by the teacher by dividing students into several groups during learning, providing learning videos, ice breaking, and a short pause after conveying the concept can reduce students' anxiety.
Keywords: Concept Understanding, ICT, Math Anxiety, Quadratic Equation.

Introduction

Quadratic equations are compulsory material in the mathematics curriculum and are important for students to master. In the Merdeka Curriculum, quadratic equation material is presented at the Senior High School level in Phase E (Permendikbud, 2024). The learning outcome is that students can solve problems related to quadratic equations and functions.

Several studies show that students still experience problems in learning quadratic equation material (Baybayon & Lapinid, 2024; Herawaty et al., 2021; Ruli, 2021; Susilo, 2018). Several factors cause students to experience difficulties in learning quadratic equations. Baybayon & Lapinid (2024) research shows that students' understanding of prerequisite abilities and skills still needs improvement, which affects students' performance in mathematics. According to Baybayon and Lapinid, the prerequisite skills that affect student performance are differentiating quadratic equations from other types of equations and expressions, understanding what is meant by solving equations, factoring quadratic equations, and simplifying algebraic expressions. Susilo (2018), in his research, states that students are still unable to solve quadratic equations and construct new quadratic equations from the roots of other quadratic equations. In addition, Susilo revealed that students are still

inattentive when mathematics learning is given, and the lack of students desire to repeat the material that has been learned so that they have difficulty understanding the quadratic equation material. Students' difficulty in representing problems in algebraic form is also an obstacle for students in learning quadratic equations (Ruli, 2021).

The students consider math to be a difficult subject. Math is considered unpleasant and incomprehensible with difficult tasks or problems; only some are good at it (Istikomah & Wahyuni, 2018). Such feelings can trigger a certain nervousness referred to as anxiety. Math anxiety is an uncomfortable feeling that arises when facing math problems. It is related to fear and worry in certain situations related to mathematics (Sangral & Kumar, 2023). In addition, it adversely affects student achievement (Erdoğan et al., 2011; Karimi & Venkatesan, 2009; Khatoon & Mahmood, 2010). It happens because anxiety creates complexity when learning and applying mathematical concepts (Gleason, 2007).

Lyons & Beilock (2012) stated that math anxiety has the same symptoms as suffered by the body due to other causes. This is because the posterior insula, which is the part of the brain that feels pain in the body, becomes an active part of the brain in subjects with math anxiety, especially subjects with high math anxiety. Khatoon & Mahmood (2010) revealed that math anxiety is found in students from elementary school to higher education. Furthermore, the level of anxiety increases as the level of education increases (Jackson & Leffingwell, 1999). Higher levels of math anxiety occur as math materials become more complex. Therefore, students should be motivated to have higher self-confidence to solve every problem in learning mathematics.

Anxiety can be viewed from cognitive, affective, and physiological dimensions. Mus et al. (2022) reported that students with math anxiety tend to say that math is a difficult subject, dislike math, refuse to do assignments, and even skip class. It, of course, can affect their success in math exams (Istikomah et al., 2018). Choppin (2011) revealed that teachers who experience math anxiety usually rely on textbook-based teaching that emphasizes basic skills and minimal discussion activities. In addition, they need to be more skilled in implementing various mathematics learning strategies in the classroom (Swars Auslander et al., 2006).

The use of technology in learning contributes positively to students. Istikomah & Sakinah (2013) suggested that integrating Geometer Sketchpad software makes it easier for students to understand a concept. In line with this, Maharjan et al. (2022) concluded that ICT tools such as GeoGebra, Sketchup, and Microsoft Mathematics can help develop a

conceptual understanding of mathematics in schools through visualization. In addition, research Nasution et al., (2019b, 2019a) shows that using technology such as GeoGebra can reduce students' math anxiety levels. Based on the Systematic Literature Review conducted by Atoyebi & Atoyebi (2022) on whether technology-based approaches can reduce math anxiety, the results showed that 91.43% of articles stated that technology-based approaches can reduce math anxiety.

This paper aims to develop a valid, practical, and effective learning design for quadratic equation material using algebraic tile applets, which will help students understand the concept and reduce their math anxiety.

Method

This research is development research, referring to Plomp's development model, which consists of three stages: analysis, design, and development (Plomp, 2013). The material is limited to quadratic equations with rational roots. The products developed are Lesson Plans (LP), Activity Sheets (AS), and Test Questions. The instruments in this study are validation sheets, observation sheets of learning implementation, student anxiety questionnaires, and test results.

The prototypes that have been developed (LP, AS, and Test Questions) are then validated by experts, namely practitioners (teachers) and material experts (lecturers). The total score of instrument validation is expressed in the following formula.

$$IVS = \frac{\sum_{j=1}^{m} \sum_{i=1}^{n} x_{ij}}{mn}$$

with:

IVS : Instrument validation total score.

m : The number of validators.

n : The number of question items of an instrument.

x_{ij} : The score of the i-th question item of validator j.

The total instrument validation score (IVS) is then classified into three eligibility categories: feasible, feasible enough, and not feasible. Table 1 presents the conversion of IVS into feasibility categories.

Table 1. Convert the total score of instrument validation into feasibility categories.

IVS Range	Category
$3 < IVS \leq 4$	Feasible
$2 < IVS \leq 3$	Feasible enough
$1 \leq IVS \leq 2$	Not feasible

After being validated and declared feasible, the lesson plans, activity sheets, and test questions were tested in one class. The test subjects were students of class X Vocational High School. In this study, students were said to understand the concept if the test score obtained was at least 75. The student anxiety questionnaire was given two weeks before and after the implementation of learning.

Results and Discussion

At the analysis stage, the Phase E Learning Outcomes and learning objectives were reviewed. In accordance with the Merdeka Curriculum, learning outcomes in Phase E consist of four elements, namely numbers, algebra and functions, geometry, and data analysis and opportunities. In this study, the focus of learning design development is on algebra and function elements with the learning outcome that students can solve problems related to quadratic equations and functions. The learning objectives to be achieved are: (1) students can factorize quadratic forms using the Algebra Tiles Applet, (2) students can determine the solution of quadratic equations using the Algebra Tiles Applet, and (3) students can apply quadratic equations to solve contextual problems.

After the analysis stage, an *outline of* the learning design, teaching materials, test questions, math anxiety questionnaire and interview guidelines were made. The outline is presented in Table 2.

Tabel 2. Learning Design Outline

No	Aspect	Outline
1.	Lesson Plans	The time allocation used is 90 minutes which is divided into introduction, core and closing activities. In the introductory activity, the teacher provides apperception by showing a video about the application of quaternary equations in everyday life. In the core activities, the teacher demonstrates the algebraic tile app, provides ice breaking to reduce student anxiety, and provides student worksheets, provides scaffolding for students who are having difficulty, and asks students to submit discussion results. In the closing activity, the teacher provides reinforcement of learning.
2.	Teaching Materials	a. Apperception video: **Introduction to Applications of Quadratic Functions for Teens!** Source: https://www.youtube.com/watch?v=S50i77dIp9c b. Algebra Tile Applet url: https://mathsbot.com/manipulatives/tiles c. Student Activity Sheets
3.	Assessments	a. to measure understanding, a test was used. The test consisted of four questions that measured students' ability to factorize quadratic forms (one question), determine the solution of quadratic equations (two questions), and apply quadratic equations to solve contextual problems (one question). b. To measure math anxiety, an instrument in the form of a questionnaire that refers to the Scale for Assessing Math Anxiety in Secondary Education (SAMAS) developed by Yáñez-Marquina & Villardón-Gallego (2017) in the domain of math learning anxiety and math test anxiety was used.

After the outline is completed, the next step is to make it a prototype of learning steps, teaching materials, test questions, and interview guidelines. The resulting prototype is then validated by experts or practitioners (teachers). The lesson plans, worksheets, and test questions are in the Appendix. The results of the validation of lesson plans, worksheets, and test questions are presented in Table 3.

Table 3. Results of the Developed Prototype validation

No	Instrument	IVS	Description
1.	Lesson Plans	4	Feasible
2.	Activity Sheets	3,92	Feasible
3.	Test Questions	4	Feasible

After the lesson plans, activity sheets, and test questions were declared feasible, the learning design was implemented. The learning begins with an apperception video that presents the application of quadratic equations in daily life such as the design of roller coasters, the calculation of reaction speed, the trajectory of a cannonball, the trajectory of an asteroid, and calculating the time of a water-filled balloon dropped from a certain height. When the video was shown, students looked enthusiastic by paying close attention. Students were also motivated to learn more about quadratic equations by asking several questions related to the apperception video. After the students are motivated, the teacher conveys the learning objectives to the students and divides the students into 8 groups with each group consisting of 3 - 4 students.

After dividing the groups, the teacher explains the concept of quadratic equations and how to factorize quadratic equations using the Algebra Tiles Applet. The teacher uses the Algebra Tiles Applet by opening the web page (see Figure 1). The teacher also asks the students to try the Algebra Tiles Applet through the mobile devices owned by the students. Then the teacher explains the rules of using the Algebra Tiles Applet to factorize and solve quadratic equations. The teacher gives time for students to understand the rules. After that, the teacher provides ice breaking by asking students to stand up and follow the movements made by the teacher. Students look enthusiastic in ice breaking and do not look tense. After doing enough ice breaking, the teacher then gives the worksheets to the students. The teacher asks students to discuss in their respective groups to solve the problems in the worksheet. The teacher monitored the students' discussion by seeing the progress of each group's worksheet.

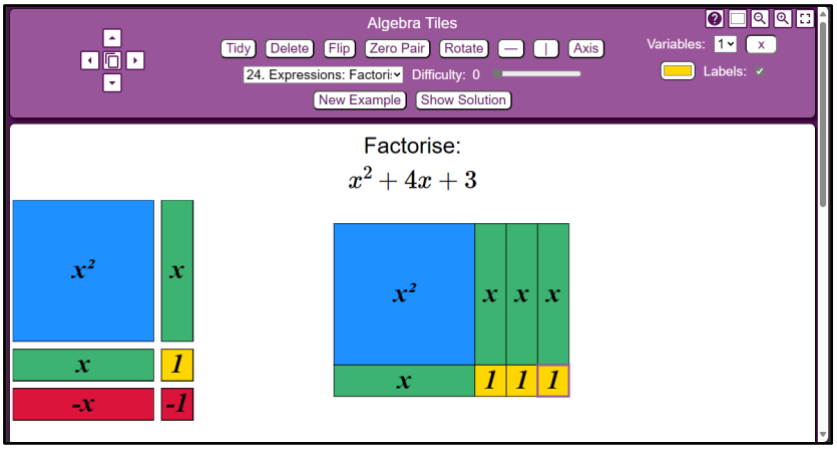

Figure 1. The online Algebra Tiles Applet that the teacher uses.

Source: https://mathsbot.com/manipulatives/tiles

During the discussion, it was seen that students were enthusiastic in using the Algebra Tiles Applet. Students did not show any significant signs of anxiety such as nervousness or tension. In general, students can use the Algebra Tiles Applet to solve quadratic equations. However, there are students who are a little confused in using the Algebra Tiles Applet, so the teacher provides scaffolding by explaining to these students. The problems presented in the worksheets given to students were solved well, Figure 2 shows one of the students' work. In the problem presented in Figure 2, students are asked to factorize the quadratic form using the Algebra Tiles Applet, then the answer is drawn in the space provided.

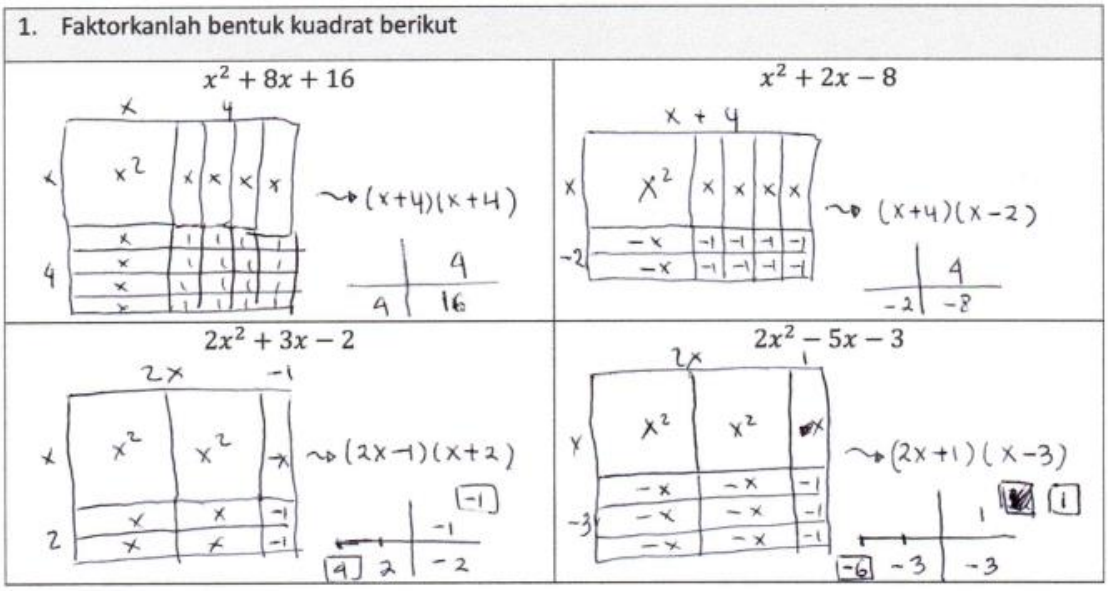

Figure 2. One of the students' work

After students solve the problems given in the worksheet, the teacher gives students the opportunity to convey the results of their discussion. The teacher tries not to point out

which group should convey the results of the discussion, this aims to prevent students from feeling nervous when appointed by the teacher. After the students delivered their discussion results, the teacher gave reinforcement and together with the students made a summary of the learning. Then the teacher gives five practice questions to students and closes the lesson.

The test was conducted on another day after learning. There were 30 students who took the test after learning. The minimum score obtained by students was 45, the maximum score was 100, and the average score was 84.25. Of the 30 students who took the test, there were 25 people who scored at least 75 (said to have understood) and 5 people who scored below 75 (said not to understand). The classical learning completeness was 83.3% which exceeded the set criteria of at least 80%. Students who did not complete (test score less than 75) were given remedial, in the form of reinforcement of quadratic equation material and corrective tests outside of school hours.

The results of the mathematics anxiety questionnaire filled out by students before learning and after learning are presented in Figure 3.

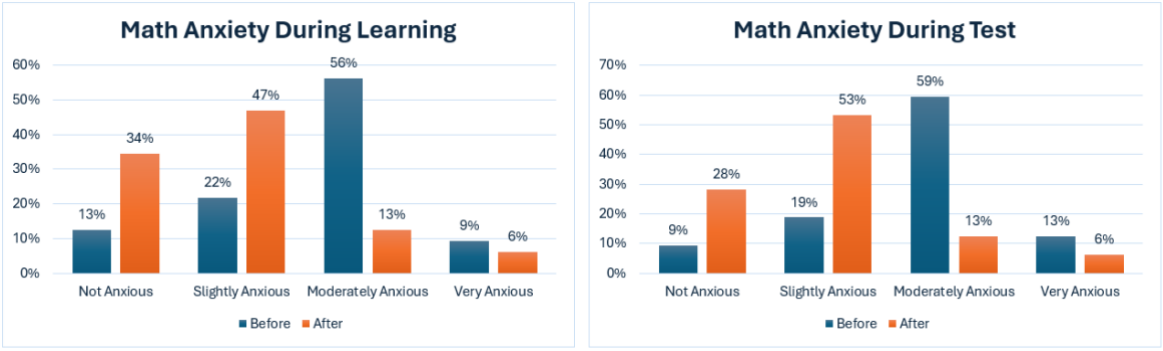

Figure 3. Math Anxiety Level during Learning and Test

The number of students who did not experience anxiety increased by 21%, students with "slightly anxious" anxiety level also increased by 25%, students with "moderately anxious" anxiety level decreased by 43%, and students with "very anxious" anxiety level decreased by 3%. When facing the test, the number of students who were not anxious increased by 19%, students with an anxiety level of "slightly anxious" also increased by 34%, students with an anxiety level of "moderately anxious" decreased by 46%, and students with an anxiety level of "very anxious" decreased by 7%. Based on the test results, 83.3% of students were declared complete (understanding the material). Students who did not complete (test score less than 75) were given remedial, in the form of reinforcement of quadratic equation material and corrective tests outside of school hours. Based on the results of learning reflection, test results, questionnaires, and interviews with students, it is

concluded that the learning design developed and the use of ICT in the form of algebraic tile applications can reduce student anxiety during learning and make students understand the quadratic equation material.

In the learning design, the teacher starts the learning by providing apperception by showing a video of the application of quadratic equations in daily life. The use of videos on the application of quadratic equations aims to motivate students. When the video was shown, students looked enthusiastic by paying close attention. Students were also motivated to learn more about quadratic equations by asking several questions related to the apperception video. When students in the initial condition are motivated, it is expected to reduce student anxiety. This is based on research by Giriansyah & Pujiastuti (2021); Ramda & Gunur (2021), which state that learning motivation positively affects students' math anxiety. Furthermore, according to the *Cone of Experience theory*, students will remember about 40% of what is presented when videos/moving images are used. This is better than students being asked to read or only hear an explanation of the material. The display in moving images is expected to be maintained in sensor memory. The short video duration also aims to avoid too much information being processed by students to not burden short-term memory in processing further information.

In the initial activity in the core part of learning, the teacher demonstrates using the algebraic tiles applet and asks students to pay attention. Then, the teacher allows students to try to do the simulation themselves. In this section, the teacher gradually increases the level of experience in the Cone of Experience, from watching demonstrations to modelling or simulating an authentic experience using algebraic applets. The efforts made by the teacher to keep students active in the learning process aim to make the information obtained by students be stored longer. In addition, according to Atoyebi & Atoyebi (2022); Mamolo & Sugano (2023); Nasution et al., (2019b, 2019a); Trotsenko et al., (2020), the use of digital learning media can reduce students' math anxiety.

The teacher's activity design, by giving a short pause for students to understand the algebra tile rule and providing ice-breaking aims, provides an opportunity for short-term memory to process the information (in the form of algebra tile rules) that has just been given. Ice breaking is expected to reduce student anxiety because these activities can reduce student tension after learning a concept. When students are given activity sheets and asked to discuss it with group mates, this activity also aims to reduce math anxiety. The test will be

implemented at the next meeting. This aims to provide sufficient time for students to prepare, which is expected to reduce math anxiety.

The use of algebraic tile applets in learning can not only reduce student anxiety but can also help students understand factoring algebraic forms and find solutions to quadratic equations. Based on interviews with several students, it was found that they found it easier to factorize quadratic forms with the algebraic tile applet because there were concrete objects (algebraic tiles) which were then arranged to become rectangular shapes and they felt challenged for that. When they can construct the algebra tiles into a rectangular shape, they can write the math form.

From the point of view of the Genesis Instrumentation theory, the algebraic tiles and NLPD are artifacts (Verillon & Rabardel, 1995). The algebra tiles used to factorize quadratic equations and solve quadratic equations are referred to as tools. The rules of algebraic tiles and how to arrange algebraic tiles into rectangular or square shapes to solve quadratic equations or factorize quadratic forms is a technique. Schema is formed when students perform the process of factoring and finding solutions to quadratic equations by utilizing the artifacts and techniques used.

Based on the results of reflection on learning, test results, questionnaires, and interviews with students, it was found that the learning design developed and the use of ICT in the form of algebraic tile applications can reduce student anxiety during learning and make students understand the quadratic equation material.

Conclusion and Suggestion

In preparing this learning design, three stages are used, namely: analysis, design and development stages. To reduce anxiety and assist students in understanding the quadratic equation material, teachers can present learning videos in apperception activities, provide ice breaking, divide students into several small groups for discussion, use ICT (in the form of algebraic tile applications), and provide a time lag for test implementation. Students feel motivated to understand and solve quadratic equations because they can manipulate the visualization of algebraic tiles that represent quadratic shapes. Students' anxiety before and after implementing the learning design using the Algebra Tiles Applet decreased. Suggestions that can be conveyed by researchers for teachers who use algebra tiles aplet to teach quadratic equation material are that students should use a device with a large size

(screen size of at least 10 inches). Using a device with a small size can interfere with students' smoothness in manipulating algebra tiles.

References

Atoyebi, O. M., & Atoyebi, S. B. (2022). Do Technology-based Approaches Reduce Mathematics Anxiety? A Systematic Literature Review. *International Journal of Research and Innovation in Social Science (IJRISS), VI*(X).

Baybayon, G. G., & Lapinid, M. R. C. (2024). Students' common errors in quadratic equations: Towards improved mathematics performance. *Infinity Journal*, *13*(1), Article 1. https://doi.org/10.22460/infinity.v13i1.p83-98

Choppin, J. (2011). The role of local theories: Teacher knowledge and its impact on engaging students with challenging tasks. *Mathematics Education Research Journal*, *23*(1), 5–25. https://doi.org/10.1007/s13394-011-0001-8

Erdoğan, A., Kesici, Ş., & Sahin, I. (2011). *Prediction of High School Students' Mathematics Anxiety by Their Achievement Motivation and Social Comparison*. *10*.

Giriansyah, F. E., & Pujiastuti, H. (2021). Pengaruh Kecemasan Matematis dan Motivasi Belajar terhadap Prestasi Belajar Matematika. *JKPM (Jurnal Kajian Pendidikan Matematika)*, *6*(2), Article 2. https://doi.org/10.30998/jkpm.v6i2.9938

Gleason, J. (2007). Relationships between Pre-service Elementary Teachers' Mathematics Anxiety and Content Knowledge for Teaching. *Journal of Mathematical Sciences and Mathematics Education*, *3*, 39–47.

Herawaty, D., Widada, W., Gede, W., Lusiana, D., Pusvita, Y., Widiarti, Y., & Anggoro, A. F. D. (2021). The cognitive process of students understanding quadratic equations. *Journal of Physics: Conference Series*, *1731*(1), 012053. https://doi.org/10.1088/1742-6596/1731/1/012053

Istikomah, E., Irawan, E., & Mahmudin. (2018). ANALISIS HUBUNGAN TINGKAT KECEMASAN MATEMATIKA DENGAN HASIL BELAJAR MAHASISWA. *Jurnal Pendidikan Matematika Sigma Didaktika*, *6*(1), 14–21.

Istikomah, E., & Sakinah, Nor. M. (2013). Kesan Penggunaan Perisian Geometer's Sketchpad Ke Atas Kefahaman Konsep Matematik Pelajar (The Effects of Using Geometer's Sketchpad on Students' Conceptual Understanding of Mathematics). *Jurnal Pendidikan Matematik, 1*(2), 1–13.

Istikomah, E., & Wahyuni, A. (2018). Student's Mathematics Anxiety on The Use of Technology in Mathematics Learning. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, *3*(2), Article 2. https://doi.org/10.23917/jramathedu.v3i2.6364

Jackson, C. D., & Leffingwell, R. J. (1999). The Role of Instructors in Creating Math Anxiety in Students from Kindergarten through College. *The Mathematics Teacher*, *92*(7), 583–586. JSTOR.

Karimi, A., & Venkatesan, S. (2009). Mathematics Anxiety, Mathematics Performance and Academic Hardiness in High School Students. *International Journal of Educational Sciences*, *1*(1), 33–37. https://doi.org/10.1080/09751122.2009.11889973

Khatoon, T., & Mahmood, S. (2010). Mathematics anxiety among secondary school students in India and its relationship to achievement in mathematics. *European Journal of Social Sciences*, *16*, 75–86.

Lyons, I., & Beilock, S. (2012). When Math Hurts: Math Anxiety Predicts Pain Network Activation in Anticipation of Doing Math. *PloS One*, *7*, e48076. https://doi.org/10.1371/journal.pone.0048076

Maharjan, M., Dahal, N., & Pant, B. (2022). *ICTs into mathematical instructions for meaningful teaching and learning*. *2*, 341–350. https://doi.org/10.25082/AMLER.2022.02.004

Mamolo, L. A., & Sugano, S. G. C. (2023). Digital interactive app and students' mathematics self-efficacy, anxiety, and achievement in the "new normal". *E-Learning and Digital Media*, 20427530231167646. https://doi.org/10.1177/20427530231167646

Mus, H. A., Muriana, Joy, I. E., Alhaji, A. Y., & Chistiana, A. (2022). Causes of Mathematics Phobia Among Secondary School Students: Implication for Counselling in Ijumu Local Goverment Area of Kogi State, Nigeria. *International Journal of Education and Research*, *10*(11).

Nasution, S. H., Qohar, A., & Susiswo. (2019a). Computer-Assisted Assessment Model to Decrease Math Anxiety And Increase Mathematical Self Efficacy of Junior High School Students. *Journal of Physics: Conference Series*, *1227*(1), 012011. https://doi.org/10.1088/1742-6596/1227/1/012011

Nasution, S. H., Qohar, A., & Susiswo. (2019b). Interactive Task Development of The Area and Perimeter of Rectangle to Reduce The Anxiety of Secondary Students in Doing Mathematics Task. *Journal of Physics: Conference Series*, *1227*(1), 012010. https://doi.org/10.1088/1742-6596/1227/1/012010

Permendikbud. (2024). *Peraturan Meneteri Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia Nomor 8 Tahun 2024 Tentang Standar Isi pada Pendidikan Anak Usia Dini, Jenjang Pendidikan Dasar, dan Jenjang Pendidikan Menengah*. jdih.kemdikbud.go.id.

Plomp, T. (2013). An Introduction to Educational Design Research. In T. Plomp & N. Nieveen (Eds.). *Educational Design Research Part A: An Introduction*, 10–51.

Ramda, A. H., & Gunur, B. (2021). Hubungan Kecemasan Matematika dan Motivasi Belaajr dengan Prestasi Belajar Matematika Siswa. *Jurnal Review Pembelajaran Matematika*, *6*(2), 130–140. https://doi.org/10.15642/jrpm.2021.6.2.130-140

Ruli, R. M. (2021). Identifikasi Hambatan Belajar Siswa pada Konsep Persamaan Kuadrat. *Jurnal Pembelajaran Matematika Inovatif*, *4*(4). https://doi.org/10.22460/jpmi.v4i4.p%25p

Sangral, M., & Kumar, S. (2023). MATHEMATICAL ANXIETY AMONG SECONDARY SCHOOL STUDENTS IN RELATION TO THEIR GENDER, LOCALITY AND TYPES OF SCHOOLS. *EPRA International Journal of Multidisciplinary Research (IJMR)*, *9*(10), Article 10.

Susilo, G. (2018). Analisis Kesulitan Siswa Sekolah Menengah Atas Kota Balikpapan dalam Memecahkan Masalah yang berkaitan dengan Persamaan Kuadrat dan Fungsi Kuadrat Tahun Ajaran 2014/2015. *De Fermat: Jurnal Pendidikan Matematika*, *1*(2), 1–11. https://doi.org/10.36277/defermat.v1i2.19

Swars Auslander, S., Daane, C., & Giesen, J. (2006). Mathematics Anxiety and Mathematics Teacher Efficacy: What is the Relationship in Elementary Preservice Teachers? *School Science and Mathematics*, *106*, 306–315. https://doi.org/10.1111/j.1949-8594.2006.tb17921.x

Trotsenko, O., Bilyk, O., & Pyliachyk, N. (2020). ICT AS A TOOL FOR REDUCING ANXIETY IN PRE-SERVICE FOREIGN LANGUAGE TEACHERS' PRACTICUM. *Information Technologies and Learning Tools*, *78*(4), Article 4. https://doi.org/10.33407/itlt.v78i4.3135

Verillon, P., & Rabardel, P. (1995). Cognition and artifacts: A contribution to the study of though in relation to instrumented activity. *European Journal of Psychology of Education*, *10*(1), 77. https://doi.org/10.1007/BF03172796

Yáñez-Marquina, L., & Villardón-Gallego, L. (2017). Math anxiety, a hierarchical construct: Development and validation of the Scale for Assessing Math Anxiety in Secondary education. *Ansiedad y Estrés*, *23*(2), 59–65. https://doi.org/10.1016/j.anyes.2017.10.001