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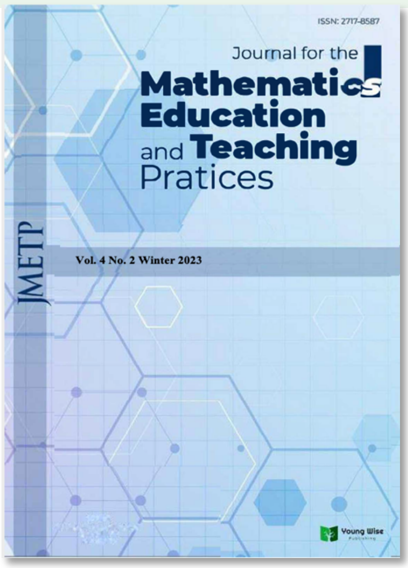

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Research Article

Pre-service teachers' mindset and persistence in college algebra and statistics units of practice

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Abstract

Understanding the mindset and persistence traits of pre-service teachers (PSTs) is significant as these traits impact future teacher engagement with classroom materials and their future work by influencing student performance. PSTs' persistence in two college courses was measured, and pre- and post- course scores were compared looking at if their mindset and persistence improved over their content courses. Our study would recommend reconsidering the standards and course expectations of engagement, what improvements can be made to learning in various modalities, and that CoVid-19 PSTs may be more accepting and flexible. Shifts to learning, the challenges, and methods should be studied and compared to pre-CoVid-19 studies to understand CoVid-19 shifts in ideologies, both in the moment and long term.

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Introduction

Teacher education programs (TEPs) have evolved from apprentice training into bachelor's programs. Many educators sought to complete undergraduate and graduate degrees focused on pedagogical methods, specific content areas, and/or administrative decisions during the CoVid-19 pandemic. The majority of classroom experiences and learning towards a bachelor's degree before CoVid-19 was done face-to-face (f2f), with anecdotal stories of taking courses online or virtually. However, CoVid-19 drastically changed how teacher candidates may be expected to engage, learn, and teach in their careers as educators. Teacher candidates who started their degree programs before and during CoVid-19 may now be approaching their current coursework (and future classroom) with changes to their mindset and persistence, particularly in mathematics.

Pre-Service Teachers (PSTs)are potential educators seeking certification to teach in particular grade bands and in a specific content area such as science, English, or mathematics (as was the focus of this paper). PSTs are a unique population as they have dual views when engaging with course materials. First, PSTs are students in their current learning experiences and second, they are future educators who have the potential to influence hundreds of students over the course of their careers. This duality can take multiple positive (or not so positive) twists or turns that could influence PSTs mindset and persistence. These changes may also extend to PSTs' future students. (Chen et al., 2014; 2018; 2021).

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Initial mindset studies considered 5th grade students' views of their learning and ability (Diener & Dweck, 1978). Now, almost 40 years later, Boaler and Dweck (2016) have expanded-and refined-the definitions of mindset and persistence for use in the mathematics classroom. Research about a growth mindset – the belief that PSTs have not yet learning enough and having a fixed mindset- the belief that PSTs cannot learn anything new, is not the sole variable to consider (Gutshall, 2014; Pelletier et al., 2020; Stephens et al., 2022). PSTs also need the persistence to continue learning (Chen et al., 2014). Duckworth and Quinn (2009) use the idea of grit - the persistence to achieve long-term goals and ambitions. Both mindset and persistence have seen positive-outcome studies (Andersen & Nielsen, 2016; Broomhead et al., 2012; Burnette et al., 2018; Clements et al., 2011; Daly et al., 2007) and mixed-outcome studies (Brougham, 2016; Burnette et al., 2018; Orosz et al., 2017; Rhew, 2017). Recently, Author et al. (2020) suggested that PSTs who engage in professional learning focused on challenging tasks that engaged the PSTs in understanding their mindset and persistence can show changes to their mindset and persistence in weekly sessions over five weeks.

Literature Review

The recent global pandemic changed how educators engage with their current students and how future teachers engage in learning the craft of teaching. For many PSTs across TEPs, this included learning via virtual or hybrid conditions. With such immediate changes, the mindset and persistence of many, including PSTs, may have shifted. Our study focused on PSTs' mathematics content courses where learning materials aligned to CCSS-M state standards but focused within the units of practice of College Algebra and Statistics for those intending to teach 8th grade and below.

Mindset

Mindset, as defined by Dweck and Leggett (1988), is a person's established set of attitudes given a particular topic, particularly whether intelligence and talent are of a fixed or malleable quality. While mindset is often viewed as a motivational variable, with entity or incremental views of motivation explaining a person's approach to a situation, mindset can be a cognitive or behavioral pattern as well. A person with a performance-oriented, or helpless behavior pattern, will work to gain positive judgments of their efforts and avoid negative judgments of their social attributes. A person with a developmental, or learning, mindset (also known as a mastery-oriented behavior pattern) will be concerned with increasing their social competence and developing relationships. Those with fixed-mindset focus on their ability to successfully complete tasks when challenged; whereas those with growth-mindset focus on not yet having the ability to successfully complete tasks when challenged (Boaler & Dweck, 2016; Dweck, 2006). Behavioral patterns as an individual can move between categories even throughout the same situation.

Interventions to influence mindsets have become increasingly prevalent in the literature (Author, 2020; Cartwright & Hallar, 2018; Cribbs et al., 2021; Lee et al., 2021). Yeager and Dweck (2012) described a number of interventions aimed at improving student mindset, as well as four key components to help develop mindset: goals, effort, attribution for setbacks, and engagement despite setbacks. Studies have focused on the first and second components-goals and effort, respectively (Duckworth & Quinn, 2009; Lin-Siegler et al., 2016; Robertson-Kraft & Duckworth, 2014; Schmidt et al., 2017; Yeager & Dweck, 2012). However, not many studies have focused on using the third and fourth components-attribution for setbacks and engagement despite setbacks. Our study focused on the mindset PSTs had as they approached mathematics content courses from as future educators.

Research with PSTs has shown that mindset does not necessarily change during their university experience, but that PSTs can change their view of how working with students can be impactful (Pelletier et al., 2020). In a study of PSTs (both at the beginning of their program and research on those in their final clinical experience), Gutshall (2014) noticed that while some first semester PSTs had a fixed mindset regarding ability, almost all of those in their final clinical setting had shifted towards a neutral or growth mindset. PSTs who understand classroom priorities and risks associated with a more fixed or growth mindset, while teaching and engaging their future students, may assist with easing the current mathematics anxiety levels.

Persistence

Previous K-12 studies defined *persistence* as how students continue to engage in mathematical tasks despite facing challenges (Boaler & Staples, 2008) and students' perception of challenging mathematics tasks (Howard, 2008;

Montague & Applegate, 2000). For example, Hong et al. (1999) noticed when growth mindset students attempted challenging tasks, they felt residual feelings of accomplishment and persistence. For higher education students, Shen, Miele and Vasilyeva (2016) suggested that knowing how challenging tasks were perceived may suggest why persistence was demonstrated. Influencing students' persistence may likely require professional development by classroom teachers.

PSTs prior learning experiences and in-service educators' professional development can impact interactions with students (Gutshall, 2014; Truax, 2018). The importance of professional learning begins during preservice experiences and should not be ignored until teachers are in the field (Menanix, 2015), especially in regards to how students approach mathematical tasks. There has been insufficient research into persistence in higher education, particularly how PSTs approach mathematics content courses from the perspective of future educators (Hourigan et al., 2016; Lazar, 2007; Yorke & Knight, 2004), which this study looks to address. Unlike other university-level students, PSTs are students who are developing their conceptualization of persistence, instructional practices, and perception of challenging tasks from the perspective of both a student and a future educator.

PSTs

PSTs' engagement with mindset and persistence professional learning opportunities may lead them towards a growth mindset and increasing their persistence when challenged (Author, 2020). Furthermore, shifting PSTs' professional mindset and persistence early in their educational programs may shape how they affect the mindset and persistence of future students. Engaging PSTs in coursework that includes a focus on their mindset and persistence is multi-fold.

First, PSTs are a unique population who are learning how to engage with their future students while engaging in more abstract methods of the concrete concepts learned in their K-12 coursework; however, some PSTs are still developing their mathematical understanding as a student themselves (Campbell et al., 2014). Second, PSTs will be educating multiple generations of students. As such, PSTs are one of the largest groups that are going to influence and consistently engage with individuals under the age of 18. Finally, within each K-12 classroom there are future generations of educators. By engaging with growth mindset and persistence during K-12 education, the changes in classroom culture can result in greater mathematical understanding (Fraser, 2018). By building mindset and persistence into preservice programs (Paunesku et al., 2015) as long-term practices rather than one-time experiences (Aronson et al., 2002; Blackwell et al., 2007), multiple generations of educators will be influenced. Therefore, including practices in content courses, such as the units of practice that include College Algebra and Statistics, PSTs engage in TEPs with the ability to promote changes in views of intelligence might be an effective way to change how future K-12 students view mathematics.

University level mathematics content

Although there are many mathematical areas PSTs will engage with during their training toward becoming an educator as part of their university-level mathematics content courses, the two areas of focus for our study took place during the units of practice focused on Algebra and Statistics.

College Algebra. College algebra (which includes material from high school Algebra II and Pre-Calculus courses) has long been part of remedial mathematics course sequences (Bailey et al., 2010), with research demonstrating enrollment in remedial courses having mixed effects (Boatman & Long, 2018; Calcagno & Long, 2008; Martorell & McFarlin Jr, 2011; Scott-Clayton & Rodriguez, 2015). Some studies saw a benefit, such as when university students took corequisite courses for Algebra, the classes that focused on using learning strategies focused on mindset concepts saw better test scores (Montalbano, 2021). Additionally, Florida's college system explored remedial mathematics programs success reforms attempted were researched and perceived as having changed the attitudes of stakeholders within the institution which likely resulted in student perceived success (Mokher et al., 2020). However, Ngo and Kosiewicz (2017) noticed that at California Community College, students enrolled in a multi-semester Algebra course saw significantly decreased student persistence and success. Thus, it is necessary to continue to study the benefit of direct teaching of learning mindset and persistence strategies in College Algebra courses.

Statistics. Statistics is another university level course that is often required. Positive results from Schau and Emmioğlu (2012) found that 2,200 university students' attitudes towards statistics decreased or stayed constant as they progressed through their statistics course. Whereas Carlson and Winquist (2011) negative results indicated that when statistics courses had over 250 students experience a semester-long workbook statistics curriculum that students had more confidence in their ability to perform and understand statistics and noticed they liked statistics more. Yet when compared to the control group, students still thought statistics was more difficult when the workbook was used. More recently, Xu et al. (2020) noticed mixed results when they considered that for approximately 2,000 students surveyed that the analysis demonstrated that students' statistics attitudes vary considerably across statistics instructors. Moreover, students' expected grades are instructor-associated are changes that form from students' positive attitudes about statistics.

Our Study

Understanding the mindset and persistence of PSTs is significant as research often reacts to learning outcomes based on standardized testing of elementary and secondary students. Could improving PSTs' mindset and persistence make a difference in their engagement with materials and in the long-term future adjust their future students' scores by reducing student anxiety? By studying mindset and persistence of PSTs, changes can be made to classroom instruction in a proactive rather than reactive manner. The researchers know this question is longitudinal and unanswerable at the current research level with CoVid-19; however, the researchers propose to start by looking at the difference between two PSTs groups enrolled in elementary content-based mathematics courses focusing on the units of practice of College Algebra and Statistics.

Having persistence assists in PSTs understanding that there will be bad days, but the next attempt they makes holds the possibility of success. PSTs need this practice from the student perspective and know how to assist their future students to productively struggle. As PSTs have continued to develop and learn during CoVid-19, this is ever more significant as PSTs face teaching and engaging students using alternative methods while also being challenged to redefine classroom management and associate with parents, administration, and other educational professionals. Therefore, our research questions were:

- Did the mindset and persistence of PSTs shift when engaging in coursework over two units of practice that used college algebra and statistics in face-to-face delivery methods before and during CoVid-19? Furthermore, did PSTs mindset and persistence change over the course of each individual unit?

Method

This study was guided by the concepts of PSTs' mindset and persistence while engaged in mathematics content-specific coursework. IRB approval was obtained, and data collected from elementary PSTs' content coursework in different states. Southern University State data was collected during the Fall 2019 semester before any indications of CoVid-19 were being mentioned in the classroom and class ran f2f as typically had been done in previous semesters. Northeastern State data was collected during the Fall 2020 semester while CoVid-19 continued to evolve. Classes for the studied at Northeastern State were done in a hybrid fashion with Day 1 each week with half the class f2f one day, the other half attending remotely; Day 2 each week had students shift attending opposite of the previous class period, and Day 3 each week alternating f2f versus remote each week. This study looked for differences in mindset and persistence for PSTs in pre- and during-pandemic groups.

Data sources

After obtaining IRB approval and PST consent for each study, comparisons within each group and between groups were analyzed. This study took place on two college campuses during the PSTs mathematic-specific content coursework required for state licensure. Southern University State was a small liberal arts college (SMLC) in a larger midwestern city, where the primary sources of employment are multiple medical centers/hospitals, several other SMLCs, and various manufactures/factories.

All data for Southern University State was collected and completed before CoVid-19 was known to exist in the United States. Southern University State Unit One covered topics that are commonly found in College Algebra coursework such as number systems and their representations, creating and understanding sets etc. Unit Two covered statistical topics that are found in foundational statistics coursework such as probability, the normal curve, z-scores/using tables, etc. Northeastern State was a medium-sized university in a small midwestern city, where the primary sources of employment were the local hospital, the university, and a manufacturing factory. All data for Northeastern State was collected and completed using CoVid-19 mitigation procedures for research and teaching as the university was f2f for the 2020-2021 school year.

Participants

Participating PSTs were mostly in their freshman/sophomore years of post-secondary education and also include several transfer students. PSTs were taking the courses as part of elementary or early childhood state licensure program and their major degree requirements. Approximately 25 PSTs from Southern University State and 150 PSTs from Northeastern State were eligible to take the surveys. Demographically, Southern University State had 1 PST of color and 24 white PSTs while Northeastern State had 3 PSTs of color, 123 white PSTs, and the remaining did not identify. Participating PSTs consented, completed each survey at least once, and completed the coursework. Due to the nature of online survey's, some PSTs submitted surveys multiple times. Only the original submission was used. PSTs participation in the study included short surveys about their mindset and persistence several times during their coursework. Only survey data was collected, and no follow up interviews or surveys were asked to be completed after course completion. Participating PSTs were included in the data set when they engaged with the surveys each of the three times: pre-unit 1, post-unit 1/pre-unit 2, and post unit 2. Based on the inclusion criteria, 17 PSTs participated from Southern University State and 102 PSTs from Northeastern State were included in the final analysis.

Table 1. Participants demographics based on university attending

	Southern University State (SUS)		***Northeastern State (NS)***	
Race	**Male**	**Female**	**Male**	**Female**
Students of Color	1	0	*0*	*3*
White/ Caucasian	4	12	*4*	*95*

Measurement instruments

To analyze PSTs' mindset and persistence, two quantitative measures were used before and after each unit. The post-survey of unit 1 also served as the pre-survey of unit 2. The 8-question Theory of Intelligence scale was used to measure PSTs' mindset (Dweck, 2006; Levy et al., 1998), and PSTs' persistence was measured using the 8-question Grit-*S* scale (Duckworth et al., 2007).

Theory of Intelligence. The *Theory of Intelligence* was used to measure PSTs' mindset that was validated by Levy et al. (1998). Responses were validated between the 3-item and 8-item correlated between 0.83 and 0.92 (Levy et al., 1998) and has been used in studies with both undergraduates and PSTs (Choi, 2018; Christopher, 2018; Gutshall, 2014; Kassaee, 2016). Our study used the 8-question version. The survey consists of two subscales: fixed-mindset and growth-mindset questions which have been modified to have a focus on mathematics. If the original question asked respondents to rate the degree to which, "Your intelligence is something very basic about you that you can't change very much;" the mathematics-adapted questions were, "Your math intelligence is something very basic about you that you can't change very much."

Grit-S. The Grit-*S* (8 questions) was used to measure the PSTs' persistence and was adapted from the 12-item Grit-*O* (Duckworth & Quinn, 2009). The Grit-*S* is shorter and psychometrically stronger. The Grit-*O* and Grit-*S* surveys were determined to show adequate internal consistency and interrelation with $r = .59$ ($p < 0.001$), after multiple comparison studies were completed. The Grit-*S* 8-item measure has two subscales, the perseverance of effort factor and the consistency of the interest factor. The Grit-*S* questions were adapted to look at students' trait-level perseverance and passion for long-term goals in mathematics. When the original question asked respondents to rate the degree to which, "I am a diligent worker," the adapted question was, "I am a diligent worker in math class."

Collection procedures and analysis

Participating PSTs accessed and completed the survey using an secure online link. PSTs completed the same survey three times over two, specific units of practice aligned between the Southern University State that was also covered in Northeastern State. The pre-survey was completed at the start of both courses of the fall semester, mid-survey was completed between units, and a post-survey that was completed at the end of the second unit. Surveys for Southern University State were allowed to be completed during the course in person or online within 5 days of opening; however, due to CoVid-19 mitigation measures, Northeastern State surveys were given solely for PSTs to complete on their own and were open for 5 days each time. In both courses extra credit points were offered for completing the survey measures (approximately a grade increase of 5% overall). PSTs participation in the study was not connected to their ability to receive the extra credit; they were offered alternative assignments to gain extra credit if they chose not to participate in the study.

The survey consisted of three parts: the first part asked for specific course/instructor information and other demographic data; the second part asked mathematics-focused variations of the Theory of Intelligence questions; the third part asked mathematics-focused Grit-*S* questions.

To answer the question of mindset/persistence shifts occurring within the two units of practice, scores were looked at individually for each university group. To find if each PSTs' mindset and persistence had improved, PSTs' ending scores were compared to their starting score, then divided by the starting score and multiplied by 100 to find the percentage value of better for mindset and persistence. PSTs shifts in mindset and persistence were labeled as positive, neutral, or negative based their percentage value.

Results

Our first research questioned considered whether the mindset and persistence of PSTs change, for the better, when engaging in coursework over two units of practice that used College Algebra and Statistics in f2f delivery methods before and during CoVid-19. Table 2 compares each universities' PSTs that demonstrated improved mindset and persistence scores within the college algebra and statistics units of practice. Northeastern State offered multiple sections across multiple instructors, whereas Southern University State offered one section of each course taught by the same instructor.

Table 2. Shift in mindset and persistence by university

Southern University State			Northeastern State		
Unit of Study	**Mindset**	**Persistence**	**Unit of Study**	**Mindset**	**Persistence**
College Algebra (n = 13)*	3	3	College Algebra (n = 85)*	34	44
Statistics (n = 17)*	12	5	Statistics (n = 88)*	40	40

*PSTs with a negative shift were not counted as a shift

During f2f delivery to PSTs at Southern University State, three student's mindset and three PST's persistence improved, shifting towards a growth mindset and higher persistence levels, respectively, after engaging with College Algebra materials. Additionally, during f2f delivery of statistics twelve PST's mindsets shifted more towards growth mindset and five PSTs shifted towards higher persistence levels.

During hybrid delivery at Northeastern State, 34 PST's mindset and 44 PST's persistence improved, shifting towards growth mindset and higher persistence levels, when engaged with College Algebra materials. During hybrid delivery of statistics content, 40 PST's mindsets shifted more towards growth mindset and higher persistence levels.

For f2f delivery the number of PSTs surveyed as shifting their mindset for the better increased 300%; whereas in the hybrid course the number of PSTs who surveyed as shifting their mindset for the better increased approximately 188%. Based on the values of mindset and persistence during hybrid learning, PSTs self-reported less shifts towards a growth mindset but more PSTs self-reported shifts towards higher persistence levels.

Discussion

Programs within teacher education have evolved over the last century as the majority have placed a greater emphasis on classroom engagement and experiences. Before CoVid-19, few universities offered the option of using virtual/remote learning and rather focused on f2f engagement and instruction with PSTs. However, CoVid-19 drastically caused almost all universities to pivot towards some variation of online or hybrid learning for PSTs. Having these experiences has changed how teacher candidates were expected to engage, learn, and teach in preparation for their future educational careers. Therefore, this study focused on looking at PSTs who were in the beginning stages of their programs before/during CoVid-19 to consider if improvements to their mindset and persistence could be observed via a self-reported survey, taken in their mathematics-content coursework.

PSTs during this study were early in their content/methods course sequence moving towards initial teacher certification. Our study saw similarities to the Gutshall (2014) study that noticed many of the participating PSTs saw their mindset improve – moving towards having a growth mindset. While some of these same PSTs' mindset moved more towards a growth mindset after the second focused unit of practice, as in Gutshall's study, PSTs mindset shifted as they progressed through their content and methods coursework. Improved PSTs mindset and persistence was starting to occur as growth mindset and higher persistence language and tasks were used within PSTs coursework.

Our study results found similarities to Panuesku et al. (2015) where long-term practices that incorporated mindset and persistence actions within coursework (rather than one-time experiences) saw the improvement of PST's mindset and persistence that could positively influence their future students' mindset and persistence in mathematics. PSTs showed improvement of their mindset and persistence in the majority points throughout the semester. As the research into mindset and persistence stems from social cognitive theory (Bandura, 1977), the differences in mindset and persistence improvement between the College Algebra and Statistics units can be explained because self-efficacy is strictly task-specific: measuring statistics self-efficacy will allow you to observe significantly better outcomes than looking at the broader measure of "math" self-efficacy (Pajares, 1996; Pajares & Miller, 1995; Perney & Ravid, 1990; Sesé Abad et al., 2015; Vigil-Colet et al., 2008; Williams, 2014).

Knowing that PSTs will demonstrate these shifts over the courses as they prepare for initial certification, they can likely continue working to improve their views of mindset and persistence in their own future classrooms. PSTs are preparing to be classroom teachers, thus understanding how to teach curriculum while still developing their mathematical understanding as a student (Campbell et al., 2014) will assist in understanding how to phrase feedback and choose tasks that may allow for shifts in their own future students' mindset and persistence. If PSTs take these improved views of their own mathematical mindset and persistence into their methods coursework and other coursework, this can assist with the change of views on multiple strategies, methods, and answers from their own future students. Similar to Mokher et al.'s (2020) recent study on remedial mathematics programs, our PSTs were surveyed with the perception of having changed their views while engaging with mathematics content and their views of success. PSTs' shifts towards a growth mindset and higher persistence levels in prerequisite mathematics content coursework could affect their how PSTs approach their methods courses. Within methods courses PSTs typically are not relearning materials, but rather engaging in the various strategies that focus on engaging their future students and/or strategies to approach tasks that will gain similar end products with differences during the interim steps. Adjusting PST mindsets towards growth and higher persistence prior to their enrollment in methods courses could positively impact their own thinking and their engagement with their future students, particularly when PST engage in challenging tasks.

Limitations and Recommendations

One major limitation of this study was the introduction of CoVid-19. The time of the second school data collection there was mask mandates, cleaning mitigation, and social distancing attempts while classes were held in an adjusted f2f manner. All PSTs were part of contact tracing, but all data collection was done before a vaccine was developed or available to PSTs. Thus, a limitation of this study was the lack of evidence collection to control for the potential outside influence of the ongoing pandemic as well as lack of evidence collection that might allow for a correction of the data collected from the study group that was not aware of the way that the pandemic would shift their daily lives and professional practice.

An additional limitation was a heavy focus on non-BIPOC due to the location of each higher institute of education and the students that attended the universities. The campuses were diverse for their location in ways such as age of students, age of faculty, sexuality, and political views. The lack of BIPOC in the elementary and early-childhood classroom is mirrored in the lack of PSTs of color in this study that can later be seen as role models in their future classrooms. Along similar lines, there are major differences between the number of PSTs that participated in mathematics educational courses and the study at Southern University State and Northeastern State during the pilot semesters of the study. Thus, these results can be applied under similar circumstances, but cautiously applied or generalized to more diverse locations or universities with early childhood and elementary TEPs.

The authors of this study have the following recommendations as CoVid-19 will continue to impact classroom learning at all levels. First, standards and course expectations of engagement with f2f learning with students does not allow this shift in mindset and persistence for PSTs to just occur. We recommend that mindset/persistence (ideas/activities/trainings) are implemented consistently throughout PSTs content and methods coursework. Second, PSTs will be engaging future students who also experienced CoVid-19 learning times and can understand what improvements can still be made to learning in various modalities, so these PSTs have awareness of current student needs. The improvements that PSTs envision should be heeded as they have a unique view and experience in the field. Third, PSTs are likely to be more accepting and flexible as they enter their future classroom about issues such as student illness, alternative engagement and teaching methods/strategies, and assessment methods, so these PSTs may be more open to engage with research-based resources, methods, and grading procedures. Going forward CoVid-19 is likely to continue to impact PSTs and how they will engage with mathematics courses as students and in their own future classrooms for years to come. The shifts to learning, the challenges, and methods should be studied and compared with pre-CoVid-19 teaching, when possible, to understand how much, CoVid-19 may have shifted ideologies in the moment and long term.

In conclusion, understanding PSTs' mindsets and persistence will have a significant impact for their engagement with teaching materials and for their future students' potential performance. PSTs' mindset and persistence in two college courses were measured and pre- and post- course scores were compared looking at how their mindset and persistence improved during the course. Educators will continue to see the shifts in learning and impact of CoVid-19 in their future classroom, yet research needs to understand how as future educators, PSTs, will take their own mathematical mindset and persistence into their future classrooms.

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Research Article

Flipped classroom style and use of AI: the example of calculus course

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Abstract

The flipped classroom is an active and interactive education method that helps instructors to promote a significant change in the teaching and learning process, inverting activities, and transform the traditional teaching and learning styles. The application of the flipped classroom style is not simple and involves the instructor's commitment and consistency to facilitate the student self-regulation of activities to promote learning, especially in such difficult subjects as mathematics, physics, chemistry, etc. However, with the nowadays development of the Artificial Intelligent (AI), a lot of possibilities to engage students into the learning process arise. The objective proposed in the current work is to discuss positive and negative aspects of the flipped modulus style and use of the AI in the flipped style method on the example of the first year Calculus course. To assess the results varied methodologies have been applied. We use cross-institutional qualitative and quantitative analysis, as well as discourse analysis to achieve our goals. The results were satisfactory. It appears that in average the student's scores in the Flipped Classroom environment are by 5% higher than the ones in the traditional classroom. Moreover, for some of the topics, the different is 14.5% in favour of the Flipped Classroom style.

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Introduction

The flipped classroom teaching model has received a lot of attention in recent years. The main goal of a flipped classroom is to enhance student learning and achievement by reversing the traditional model of a classroom, focusing class time on student understanding rather than on lecture. To accomplish this, teachers post short video lectures online for students to view at home prior to the next class session. This allows class time to be devoted to expanding on and mastering the material through collaborative learning exercises, projects, and discussions. Essentially, the homework that is typically done at home is done in the classroom, while the lectures that are usually done in the classroom are viewed at home. There are numerous potential advantages to this style of learning. However, there has been some criticism to this bold new model of teaching and learning. We direct the reader to the following papers and the references therein: (Berrett, 2012; Khan, 2011; Smith, 2012).

The outbreak of the COVID-19 pandemic which led to the closing of colleges and universities has had a significant impact on student's education. The current community need is to adopt the traditional college and university classroom to the new social and educational environment. One of the strategies is to use the flipped classroom mode see for example (Divjak et al., 2012; Linling & Abdullah, 2023).

Our goal in the current work is to study positive and negative aspects of the flipped classroom in the post-pandemic recovery and to propose ways to improve this teaching module.

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Method

Our study reports on student's perceptions of a 'Flipped Learning' experience, which was a cross institutional study, with first year business students studying calculus. Ethical approval was gained to survey students on their learning preferences and outcomes. We compare students in a traditional classroom environment to those in a flipped environment for the years 2022 and 2023.

Students with the 'Flipped Learning' experience had three stages to go through every class:

2020 *Mathematics Subject Classification.* 97B10, 97B40, 97B50.

- Pre-class Work: students watched videos, read book material and completed short quizzes.
- In-class Work: involved self-study, group works, games, applied problems and projects.
- Post-class Work: homework assignment or/and a small group project.

Students who followed the traditional classroom environment attended lectures in which theory was presented, followed by a practical homework assignment.

We present results from two surveys related to the study as well as a comparison of students responses on relevant examination questions. Students of both groups were invited to complete a 'learning experiences' survey. In addition to surveys, 10 examination questions were prepared to compare the learning outcomes of the two groups.

The "Learning Preference" survey was completed by 89 (58%) of traditional classroom students and 72 (68%) f flipped classroom students. See Table 1 and Table 2.

Table 1. Student opinions on learning preferences survey (I)

Student Opinions on Learning Preferences Survey															
Flipped Classroom (72 students)								**Traditional Classroom (89 students)**							
When I Study for Class															
When I Study for Class	←Not Very True …Very True→							When I Study for Class	←Not Very True …Very True→						
	1	2	3	4	5	6	Average		1	2	3	4	5	6	Average
I pull togrether information from different sourses such as lecture notes, videos, reading materials	0	7	14	18	24	22	0.33	I pull together information from different sources such as lecture notes, videos, reading materials	15	31	27	9	6	1	0.35
I was completing quizzes for pre-class work to make sure I understand the material I have been studying			4	9	21	38	0.53	I asked myself questions to make sure I understand the material I have been studying	39	26	18	3	3	0	0.44
I try to determine which concept I do not understand well	4	6	8	23	19	12	0.32	I try to determine which concept I do not understand well		2	22	42	19	4	0.47
Reading															
	←Not Very True …Very True→								←Not Very True …Very True→						
	1	2	3	4	5	6	Average		1	2	3	4	5	6	Average
I make up questions to help focus my reading	0	4	21	26	20	1	0.36	I make up questions to help focus my reading	47	32	7	3	2	0	0.53
When I become confused about something I go back to try to figure it out	0	2	25	23	14	8	0.35	When I become confused about something I go back to try to figure it out	0	3	10	38	28	10	0.43
Lectures															
	←Not Very True …Very True→								←Not Very True …Very True→						
	1	2	3	4	5	6	Average		1	2	3	4	5	6	Average
I would pefere having my lectures online so I can attempt them when it is best for me and as many times as I need	2	2	0	3	9	57	0.79	I would pefere having my lectures online so I can attempt them when it is best for me and as many times as I need	5	2	0	0	11	71	0.80
I have limited acess to technology	68	0	0	2	2	1	0.94								

Table 2. Student opinions on learning preferences survey (II)

Times of Learning															
	←Not Very True …Very True→							When I Study for Class	←Not Very True …Very True→						
	1	2	3	4	5	6	Average		1	2	3	4	5	6	Average
I prefer to learn new concepts and terminology from lecture	20	28	13	9	1	1	0.39	I prefer to learn new concepts and terminology from lecture either by myself	1	1	3	16	21	47	0.53
Answering questions in class and in-class activities helps me to apply new terminology and concepts	0	0	2	7	34	29	0.47	I wish we would have more in-class activities, it would help me to understand and apply new concepts and terminology better.	0	0	1	5	19	64	0.72
I learn new concepts and terminology more effective by doing lerning activities	0	0	2	6	31	33	0.46								
Workload															
	←Not Very True …Very True→								←Not Very True …Very True→						
	1	2	3	4	5	6	Average		1	2	3	4	5	6	Average
I am prepared to increase my workload to learn more effectively	24	33	11	4	0	0	0.46	I am prepared to increase my workload to learn more effectively	0	3	8	37	24	17	0.42
Completing learning activities before class adds to my workload	0	0	0	1	12	59	0.82								
Grades															
	←Not Very True …Very True→							When I Study for Class	←Not Very True …Very True→						
	1	2	3	4	5	6	Average		1	2	3	4	5	6	Average
Getting a good grade in this class is the most satisfying thing for me right now	2	10	12	22	17	9	0.31	Getting a good grade in this class is the most satisfying thing for me right now	0	6	11	31	29	12	0.35
The most important thing for me is to improve my overall grade: my main concern is getting a good grade	0	2	9	28	23	11	0.39	The most important thing for me is to improve my overall grade: my main concern is getting a good grade	0	0	1	3	48	37	0.54
I am getting frastrated when exam questions are appered to me not exactely the same as in assignments. I was expecting to be prepared for exams just by doing assignment questions	0	0	1	1	61	8	0.85								

Examination Question Comparison

Table 3. Examination question comparison

Question Topic	Flipped Classroom	Traditional Classroom
Vertex of parabola application	79.9	82.1
System of linear Equations	89.7	90.2
Differentiation: Chain Rule	94.3	87.1
Second derivative of function	97.1	82.4
Application of derivatives	96.3	83.5
Integration with substitution	82.6	79.9
Optimisation problems	81.8	78.7
Extrema of multivariable function	87.1	87
Lagrange multipliers	80.4	78.3
Area under the curve	81.1	79.4

Results

Positive Aspects of Flipped Classroom

Based on our statistics, there are lots of *positive* aspects of flipped Classroom used during the post-pandemic recovery, among them are:

Students had more control over their own learning

By providing short video lectures at home and short pre-class quizzes, students had the freedom to learn at their own pace. Students could pause or rewind the lectures, write down questions they had, and discuss them later in the class. This allowed students to take their time reviewing the material (if they needed more time to understand certain concepts) without being left behind. As a result, this improved student achievement, as well as their behavior in class.

Lecture accessibility

Having video lectures and assignments online, students forced to miss class due to illness, sports, vacations or emergencies, could catch up quickly. Also, 24/7 access to the class material allowed parents to be better prepared when attempting to help their children and gave them insight into the quality of instruction given the students.

It motivates students to collaborate

With flipped classroom the in-class time is used to master skills through collaborative projects, discussions, games, competitions. These not only encouraged students to teach and learn concepts from each other, but made them work as a team member, which is very important skill in our daily life. By allowing students to assist in their own learning, they were able to own and share the knowledge they achieve, which in turn builds confidence. On the other hand, teachers could more easily identify errors in student's thinking or applications of concepts, and are more available through one-to-one interaction.

Negative Aspects of Flipped Classroom

Despite the many positive aspects of flipped learning there were *negative* aspects as well:

It can create a digital divide

It is the necessary for students to have access to a computer and the Internet in order to view the lectures. This is particularly hard on students from low-income districts who already have limited access to such resources.

It relies on preparation and trust

Flipped classrooms are dependent on student participation. We must trust students to watch the lectures and do quizzes at home. Unfortunately, there is no way to guarantee students will oblige or cooperate with the flipped model. There is significant work required for pre-class activities The flipped learning puts an extra workload on students. Even though it was suggested students spend no more than one hour for the pre-work, some students might be spending way more time on it due to personal problems, luck of understanding of the particular material, etc.

Not naturally a test-prep form of learning

Flipped classrooms do not "teach for the test"—it does not follow the model of teaching to improve standardized test scores. However, students are still required to spend a much time preparing for state-mandated testing, which in turn interrupts the flipped classroom process. While students expecting the test questions be exactly the same as assignment questions, the Flipped Classroom Model assures creative thinking over memorisation.

Conclusion

Despite some issues, the flipped classroom is still a very effective, hands-on approach to improving student achievement and involving them in their own education, especially during the post-pandemic recovery. To improve Flipped Classroom Techniques we suggest that the College/University has to insure that students with limited computer access have a place in the computer classroom to work there. The pre-class work should be followed by a short, scored quiz—it will motivate students to prepare for the class better and it will give a teacher idea how class is prepared. Ideally, the artificial intelligence (AI) should be used for grading and generating different variants of the post-class quizzes to show immediate score to the student. Based on the outcome, when students see score right after submission of their work, they are more motivated to reflect and attempt their quiz more times. In regards of the video-lectures have to be short and dense and the pre-class quizzes should not be long. We are testing only if students understand the concepts—not the whole topic. It is recommended to use AI to turn also voice to text.

The productive in-class time will bring students better understanding of the applications of the topic. Instructor should explain to students (from day one) that they are taking this class not to pass it but to develop their logic and creative thinking. Students must know that the questions provided for assignments are not the same questions they will get in the tests, so they should study core of the concepts instead of memorising steps of each particular problem The in-class concept should be delivered in an interactive way. It is recommended to use different AI chatbots and visual design tools for the in-class activities such as group works, discussion, games, etc.

The post-class assignments would have to reflect the in-class concepts. Students have to be motivated by in-class activities to complete their post-class work. One can use students' chats to allow students to discuss hard problems in the assignment. To perform better visualization and computation in mathematics some of the studying topics might allow to use help of such AI platforms as: Wolfram alpha, Socratic, Copyscape, Tutor.ai, Gradescop, Zotero, to name a few.

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Math Teaching Practices

Van Hiele model level 5 teaching activity example for mathematically gifted students: expand polygon

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Abstract

Geometry is one of the sub-learning areas of mathematics and meaningful geometry learning includes reasoning methods such as generalizing, classifying, and inferring. Therefore, it improves students' mathematical thinking skills, increases their ability to support their thoughts with mathematical arguments, and positively affects their mathematics achievement in general. The aim of this study is to prepare an instructional activity for teaching geometry to gifted students in accordance with the 5th level they have reached in Van Hiele geometry learning levels. While preparing this teaching activity, the decomposition technique in the Pythagorean Proof Application in the study "Application of the Pythagorean Relation Expressed for Square to Other Regular Polygons and Circle" by Aslaner and İlhan (2018) was used. In the activity, the table is filled in by fulfilling the steps of disassembly and assembly in accordance with the instructions given, and a mathematical relationship is asked to be found between the polygons formed. The Expand Polygon activity can be used as an activity in the support education mathematics activities of gifted students and in the mathematics applications courses of middle school and high school students from the 7th grade onwards to improve students' reasoning and spatial skills.

To cite this article

Erben, T., (2023). P Van Hiele model level 5 teaching activity example for mathematically gifted students: expand polygon. *Journal for the Mathematics Education and Teaching Practices, 4*(2), 59-65.

Introduction

Instructional activities are structured activities that aim to provide students with the targeted skills and knowledge in a planned, organized and supervised manner (Bransford et al., 2000; Fidan, 1993). Through instructional activities, students' active participation in the process, reasoning and generalization skills on basic mathematical concepts are developed, and their ability to make mathematical abstractions and calculations are supported (Henningsen & Stein, 1997; Ministry of National Education-MoNE, 2009; Olkun & Uçar, 2007). This requires students to play an active role mentally and physically and to make an intrinsic effort through learning activities. For this reason, it is extremely important to develop activities that are appropriate for the goals set in the learning-teaching processes and to implement them successfully in the classroom environment (Özgen & Alkan, 2014). The more sensory organs the teaching activity appeals to, the better and more permanent the learning event will be, and the later the forgetting will be. Students should actively participate in the lesson because students who participate in the learning environment by using all their sensory organs can learn more easily (Demirel et al., 2002). In this context, activities in geometry teaching are important tools that strengthen the learning process by enabling students to experience abstract geometric concepts in a concrete way.

Geometry is one of the sub-learning areas of mathematics and meaningful geometry learning involves reasoning methods such as generalizing, classifying, and inferring. Therefore, it improves students' mathematical thinking skills, increases

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their ability to support their thoughts with mathematical arguments, and positively affects their mathematics achievement in general (National Council of Teachers of Mathematics-NCTM, 1989). Spatial visualization, which is an important part of geometric thinking, is defined as the ability to perceive objects from different angles, to create and apply the appearances of two and three dimensional objects in the mind (Çetin & Dane, 2004). The Van Hiele model, which is one of the geometric thinking models, is based on an understanding that geometric thinking skills in students pass through five hierarchically ordered levels. These levels are named as visual period (Level 1), analytical period (Level 2), spontaneous inference period (Level 3), inference period (Level 4) and the most advanced period (Level 5). The factor for individuals to pass these levels is their experiences; as the skills provided by these levels increase, the level of geometric thinking also increases (Demir & Kurtuluş, 2019).

For the smooth implementation of the teaching activity, the cognitive, affective, social and physiological characteristics of the target group of students and their needs based on these characteristics should be taken into consideration (Kuzgun & Deryakulu, 2004). Each student has unique qualities and differs from others. One of the most important determinants of this diversity among students is their level of intelligence. The concept of intelligence has been defined in various ways by different researchers in the literature. Generally defined as the ability to adapt to one's environment and learn through experiences, intelligence can be considered from many different perspectives (Sternberg & Detterman, 1986, as cited in Sternberg, 2005).

The concept of giftedness and talent, which is defined differently in different cultures, has an important place among the different intellectual potentials of students at the center of our education system. This concept was first used for children with abnormally rapid development or high IQ scores in intelligence tests. While special education programs for gifted children are called "gifted education", the children included in these programs are referred to as "gifted children". All these terms define giftedness by emphasizing genetic and hereditary characteristics (Feldhusen, 2005).
Giftedness in mathematics and geometry refers to a high level of ability in understanding mathematical ideas and comprehending mathematical logic, rather than simply showing a high level of ability in arithmetic calculations (Miller, 1990, as cited in Dağlıoğlu, 2004). Mathematically gifted students need different instructional designs than their peers with normal development (Erdogan & Gul, 2023). Sağır-Gürlevik (2017) evaluated the geometry levels of gifted students in terms of some variables. As a result of the study, when the Van Hiele Geometry Levels of gifted students were examined, it was seen that the Level 5 group had the highest scores in spatial and critical thinking skills. In this context, when preparing teaching activities for gifted students, these levels should be taken into consideration. For example, it is known that there are different proofs of Pythagoras theorem in geometry teaching. The most well-known proof is the visual proof that the sum of the areas of squares placed on perpendicular sides is equal to the area of the square placed on the hypotenuse length. However, Aslaner and İlhan (2018) tried to express and prove the Pythagorean theorem for other regular polygons to be drawn on the sides of the right triangle after the construction of the right triangle in Cabri II Plus program. These proofs are given as Pythagorean theorem for equilateral triangles, Pythagorean theorem for square, Pythagorean theorem for regular pentagons, Pythagorean theorem for regular hexagons and Pythagorean relation for circle. Thus, the proof was questioned and proved for other polygons and the geometry learning level was raised to a higher level.

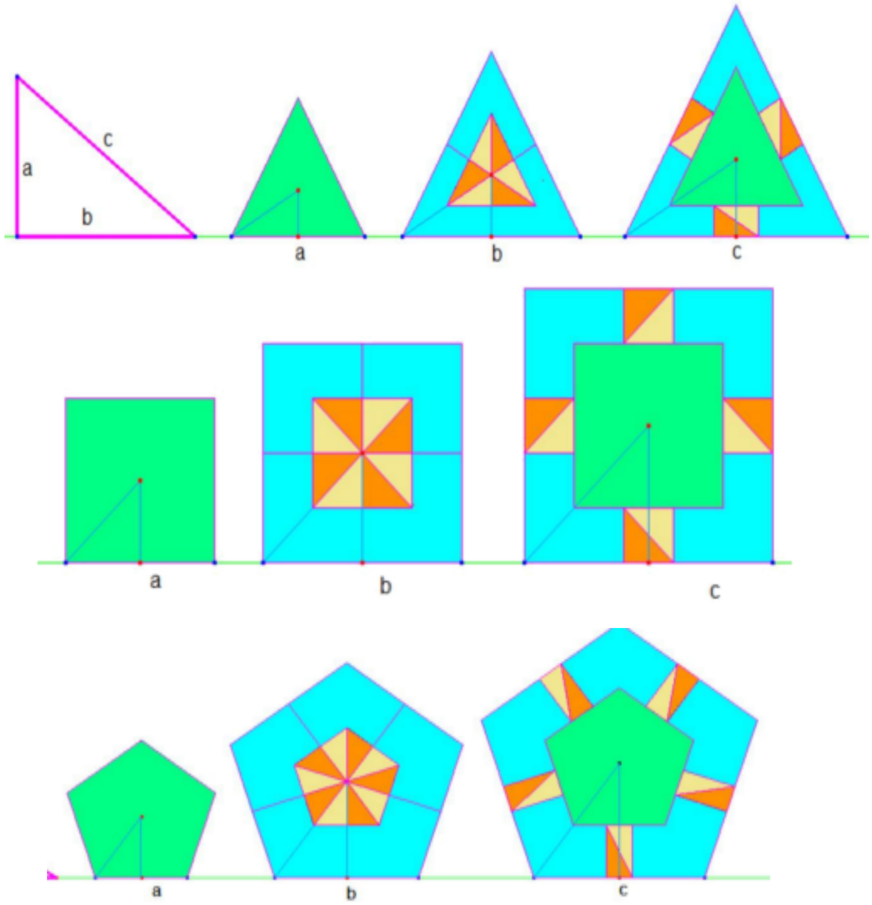

Figure 1. Application of the proof of pythagorean theorem to different polygons (Aslaner & İlhan, 2018)

Purpose of the Instructional Activity

In teaching geometry to gifted students, the aim of this study was to prepare a teaching activity suitable for the 5th level of Van Hiele geometry learning levels. While preparing this teaching activity, the decomposition technique in the Pythagorean Proof Application in the study of Aslaner and İlhan (2018) on the Application of the Pythagorean Relation Expressed for the Square to Other Regular Polygons and the Circle was used.

Information on the Teaching Activity

The related instructional outcomes of the instructional activity in the mathematics curriculum are as follows;

- Explains the side and angle properties of regular polygons.
- Draws the bisector and bisector auxiliary elements of a regular polygon.
- Uses ratio to compare lengths.
- Obtains the whole by using polygon parts.

Implementation of the Instructional Activity

Students are asked how fraction numbers are expanded. If we can expand fractions, how can we expand polygons? With the answers received, the teacher repeats the properties of polygons, the auxiliary elements of the triangle, the concepts of bisector and bisector by question and answer.

The worksheet with the prepared instruction is distributed to the student group one by one.

Note: If the physical conditions of the classroom are suitable, it is recommended to use the Geogebra program. Alternatively, A4 paper, ruler, protractor and scissors can be used to complete the instruction.

Working Paper

Method for Expanding Regular Polygons

Do the algorithm given below step by step.

Partition

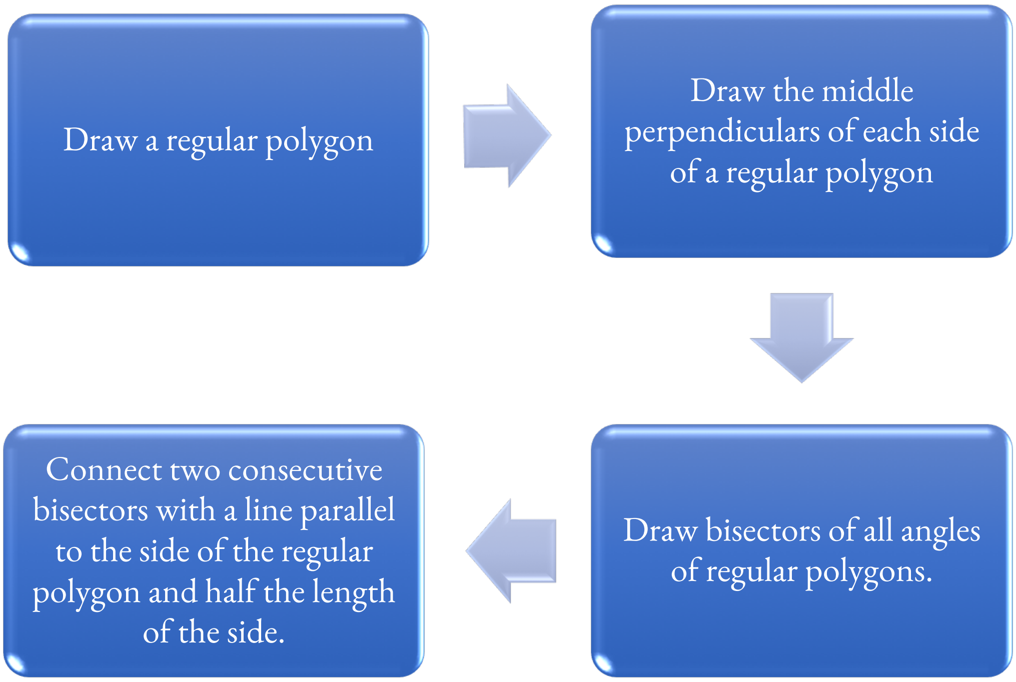

Figure 2. Shredding steps

Combination

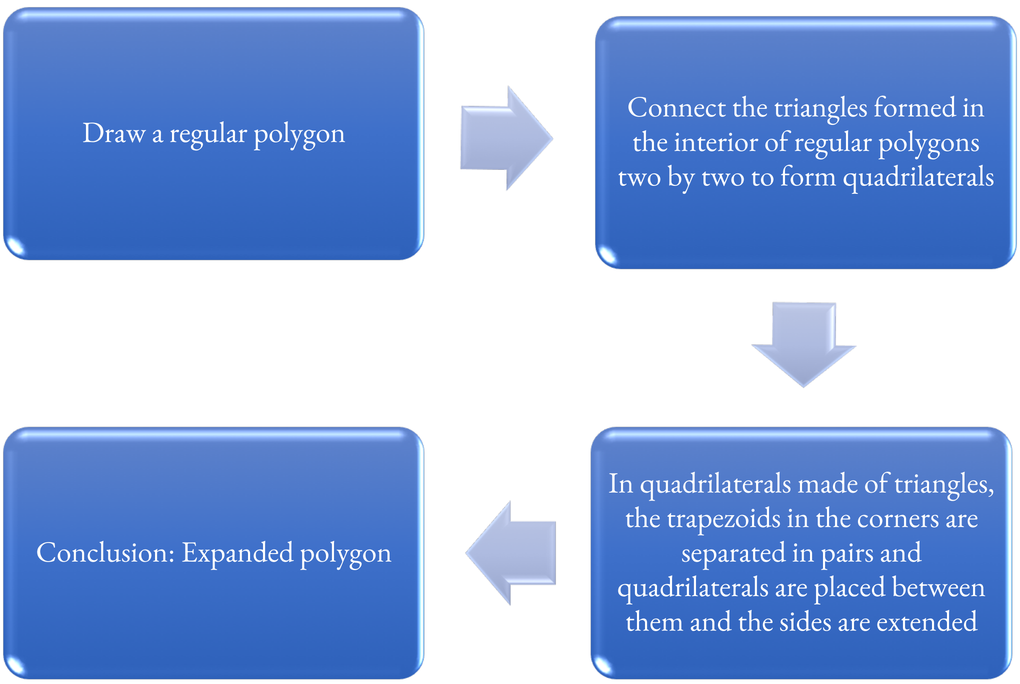

Figure 3. Combining steps

- Assessment: Find a mathematical relationship between the polygons you created.
- All the results are entered in the table and a mathematical relationship is found.

Table 2. The relationship between the side lengths of the resulting polygons

Polygon (segmented) Side Length	Polygon (formed in the inner region) Side Length	Polygon (Combined) Side Length

Examples of Structures to Be Obtained after the Algorithm

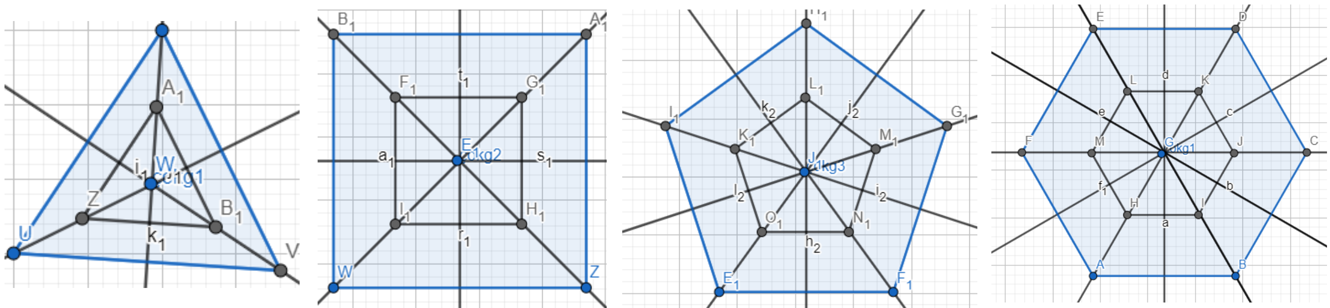

Figure 4. Connecting two points taken on two consecutive bisectors

Combining Technique

The triangle pieces formed in the inner region are removed and joined together as two-by-two quadrilaterals. The quadrilaterals are placed between the two trapezoids on the sides.

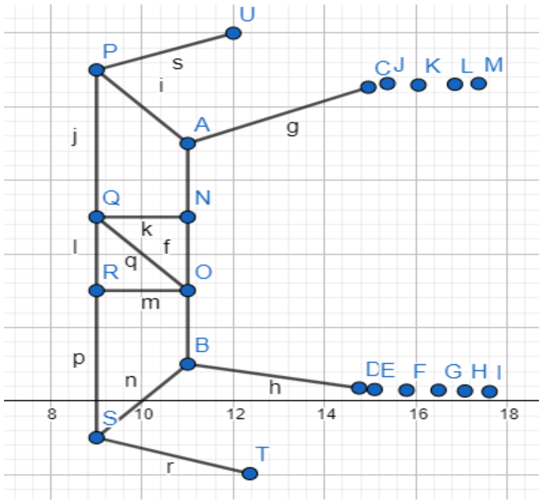

Figure 5. Section through one side of an expanded polygon

Placement of Triangles between Trapezoids on the Edge

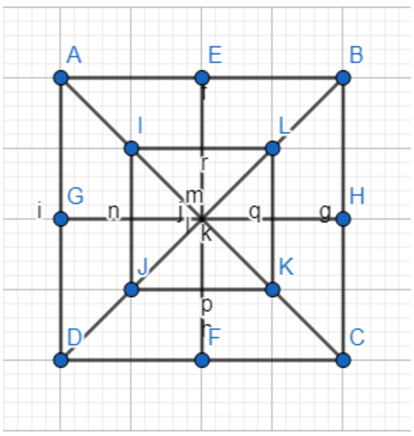

Figure 6. The Method of Segmenting Regular Polygons

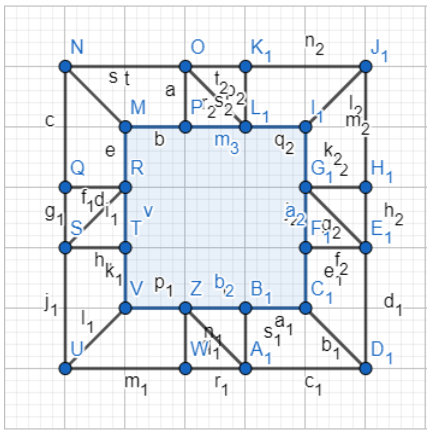

Figure 7. Expanded polygon

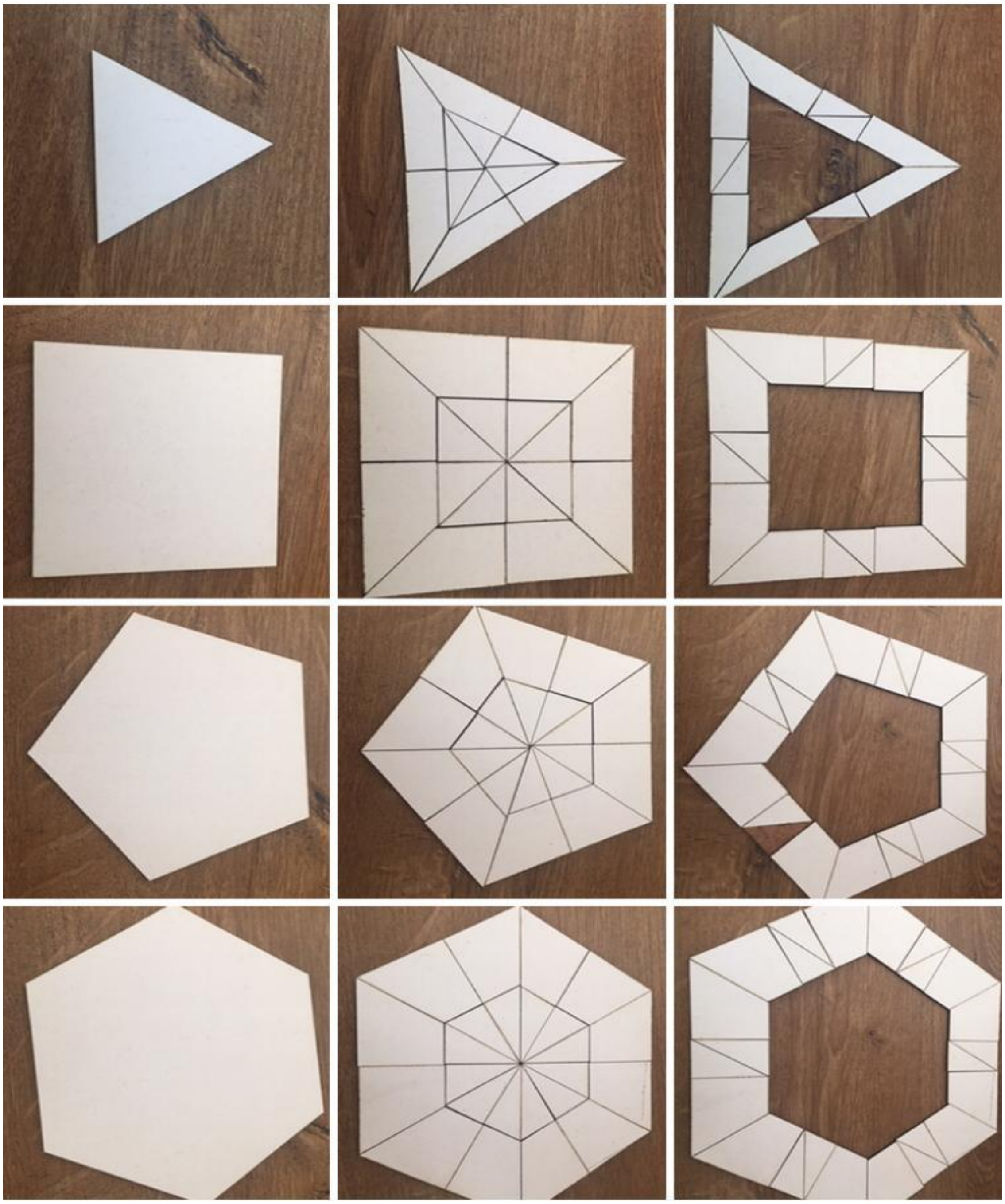

Photo 1. Structures formed when the algorithm steps are applied to papers

Conclusion and Recommendations

In geometric thinking, spatial visualization, perceiving objects from different angles, creating and applying the appearances of two and three dimensional objects in the mind are important. In this context, mathematics and geometry lessons should include activities to develop these skills. The Expand Polygon activity is an activity that will contribute to students' geometric thinking and help them discover new formulas by capturing mathematical relationships, as it is an activity that will discuss how it can be applied to polygons based on the application of expanding fraction numbers.

Expand polygon activity can be used as an activity in the support education mathematics activities of gifted students and in the mathematics applications courses of middle school and high school students from the 7^{th} grade onwards to improve students' reasoning and spatial skills. It can also be designed as a material and used in educational environments.

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Research Article

Investigating factors affecting secondary school non-achievers in mathematics before and after the pandemic

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Abstract

Acquiring knowledge in mathematics is crucial as it serves as a fundamental component for a successful academic journey. However, numerous students encounter formidable challenges, leading to unsuccessful outcomes in their mathematical courses. Therefore, identifying secondary school non-achievers in mathematics is paramount. This necessity was accentuated during the pandemic. Any physical school operation was shut down during this period, leading to an increase in non-achievers. To identify non-achievers before and after the pandemic, we constructed two relevant risk models using a binary logistic regression analysis of student engagement data. The models were applied to a particular mathematical course taught at a Greek Gymnasium. The findings proved that participation in the prescribed written tests was the main factor that affected the performance of non-achievers before the pandemic. Similarly, the risk model developed after the pandemic indicated that the same factor continued to determine student final achievement. However, the positive effect of the same factors (after the pandemic) reducing the probability of students' failure was slightly increased

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Introduction

The COVID-19 pandemic has had a significant impact on the education sector globally. Many schools and educational institutions were forced to close and switch to distance education, where students attended classes from their homes (Rapanta et al., 2021). Distance education placed additional demands on students and teachers to have appropriate equipment, internet connection, and technical skills. The lack of social interaction and physical presence at school may have affected the psychosocial student development and the educational experience. All of the above meant that some students may have had difficulties adjusting to distance learning and had reduced performance due to lack of access to resources or difficulties in self-management. In these difficulties, the effort of the teachers to adapt the educational methods they used should be highlighted. Educators have been forced to change their teaching methods to deliver effective distance learning. The upshot was that the pandemic underlined the importance of self-learning, as students needed to gain more independence in learning. The exact impact on student performance varies by region, education system, type of distance learning, and individual factors. Some students adapted better to distance learning, while others struggled. It is important to note that the approach to education during the pandemic is still evolving as situations change

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and educators and students adapt. The COVID-19 pandemic has had a significant impact on the education sector globally (Rapanta et al., 2021). Many schools and educational institutions were forced to close and switch to distance education, where students attended classes from their homes. Distance education placed additional demands on students and teachers to have appropriate equipment, internet connection and technical skills. The lack of social interaction and physical presence at school may have affected the psychosocial development of students and their educational experience. All of the above meant that some students may have had difficulties adjusting to distance learning and had reduced performance due to lack of access to resources or difficulties in self-management. In these difficulties, the effort of the teachers in terms of adapting the educational methods they used was important. Educators have been forced to adapt their teaching methods to deliver effective distance learning. The upshot of all was that the pandemic highlighted the importance of self-learning, as students needed to be more independent in their learning. The exact impact on student performance varies by region, education system, type of distance learning, and individual factors. Some students adapted better to distance learning, while others struggled. It is important to note that the approach to education during the pandemic is still evolving as situations change and educators and students adapt.

Our research interest is directed at identifying factors that affect non-achievers in mathematics after and before the COVID-19 pandemic. These factors are drawn from student engagement. Since student engagement reflects effort (Hopf et al., 2003), our research questions are:

- Did student engagement critically affect the achievement before the pandemic?
- Were factors that critically affected the student outcome before the pandemic identical to those that affected student final achievement after the pandemic?

It is crucial to emphasize that "critical achievement" implies the numeric threshold below which non-achievers are identified. To address our research questions, we formulated two risk models: one aimed at identifying factors influencing students' performance before the COVID-19 pandemic and another to identify factors affecting performance after the pandemic. We employed a binary logistic regression analysis of students' engagement data to construct these respective risk models. These data serve as potential risk factors for students' academic challenges. Each risk model discerns the data with a genuine impact on the occurrence of students' failure, highlighting statistically significant factors. Moreover, the risk models elucidate the contribution of each factor in mitigating the probability of risk occurrence.

To illustrate the development of the risk models, we present a case study centered on a specific mathematics course taught at a Greek Secondary School (Gymnasium). The following sections provide detailed insight into the construction of the risk models and the outcomes of our research.

Literature Review

Factors related to secondary school student achievement in mathematics

In the territory of secondary school student academic accomplishment, many studies associate the learning outcome with engagement (Casillas et al., 2012; Frederick et al., 2004; Marks, 2000; Willms, 2003). Simultaneously, research has established a correlation between secondary school students' achievement and their in-class effort (Hopf et al., 2003). Another critical factor is self-efficacy (McConney & Perry, 2010; Yurt, 2014). Additionally, a separate study highlights the dependence of high school students' achievement on psychological, behavioral, and demographic factors (Casillas et al., 2012). The behavioral factors mentioned are linked to students' engagement in learning activities and the overall learning process, including completed homework and study time. Lastly, the attitude of secondary school students toward mathematics (encompassing both middle school and high school students) has also been identified as a pivotal factor with a significant impact on their performance (Hemmings et al., 2011).

Predicting non-achievers in mathematics

A study has indicated that curriculum-based data can be used to predict non-achievers (Flores & Kaylor, 2007). Other studies have underlined that the teaching approach affects secondary school non-achievers in a mathematical course (Kajander et al., 2008; Xin et al., 2005), accentuating the need for early intervention. Additionally, a multiple regression analysis of students' engagement data has been used in another study to prove that cognitive and behavioral engagement affect secondary school students' failure in mathematics to a greater extent than emotional engagement (Sciarra & Seirup, 2018).

Factors affecting secondary school students' performance during the pandemic

The impact of the COVID-19 pandemic on education has attracted intense interest in the scientific community, with many publications examining the relationship between various factors and student performance during the pandemic. A key factor is the impact of isolation and social exclusion on student performance. Studies, such as that of Smith et al. (2020), report that isolation and lack of social interaction can dramatically affect students' psychological well-being and, by extension, their academic performance. In addition, technological skills and access to devices and online resources have also been examined as essential drivers. Research papers, such as that of Rapanta et al. (2021), have pointed out that lack of access to the necessary technology and online resources can impede student performance during the pandemic. Finally, support from school and family has also emerged as an essential factor. In summary, the research literature indicates that student performance during the COVID-19 pandemic is affected by many factors, including social isolation, access to technology, and school and family support. It is beneficial to continue researching this area to develop policies and practices to support education during similar crises.

Method

According to Vose (2008), risk models are constructed through a general risk management methodology. These models identify non-achievers and indicate the impact of the risk drivers on an unsuccessful outcome. A forecast model can be generated based on such drivers. A verified forecast model could lead to a warning system for students who fail their courses.

In our case, we have developed two risk models, one for the learning process before the COVID-19 pandemic and the other for the learning process after the pandemic. A Binary Logistics regression analysis was used to build the risk models (Georgakopoulos et al., 2018; Macfayden & Dawson, 2010).

Binary logistics regression

Binary logistic regression is a statistical model used to predict the probability of a discrete binary outcome (e.g. 0 or 1, yes or no) based on one or more independent variables. The mathematical (Hosmer et al. 2013) model of binary logistic regression is based on the logistic function (often known as the sigmoid function) which has the form:

$$\log(\frac{p}{1-p}) = \beta_0 + \beta_1 \cdot x_1 + \beta_2 \cdot x_2 + \ldots\ldots + \beta_\rho \cdot x_\rho$$

where:

p: the probability that the event belongs to a category.

$\beta_0, \beta_1 \ldots\ldots, \beta_p$: adjusted factors of the model.

$x_1, x_2, \ldots\ldots, x_p$: independent variable

The odds ratio for an independent variable xi is the ratio of the probability of the event belonging to one category to the probability of not belonging (Agresti, 2015):

$$\text{Odds Ratio} = \frac{\frac{p}{1-p} \; for \; x_i = a}{\frac{p}{1-p} \; for \; x_i = b}$$

where a, b are two different values of the variable x_i.

The categorization is determined by a probability threshold, establishing when to predict Category 1 or Category 0. Typically, a threshold of 0.5 is employed, wherein a probability exceeding 0.5 results in a prediction of 1, and otherwise, a prediction of 0 is made. The classification table provides a comprehensive overview of predictions, encompassing True Positive, True Negative, False Positive, and False Negative, facilitating the assessment of model performance, including metrics such as accuracy, sensitivity, specificity, and more. More specifically, the characteristics of the above methods are presented as follows:

Nagelkerke R-squared:

Introduced by Nagelkerke in 1991, Nagelkerke R-squared is a modified variant of the traditional R-squared used in logistic regression modeling. It seeks to quantify how effectively the model elucidates the variability within the response, typically a categorical variable. The Nagelkerke R-squared scale spans from 0 to 1, with 1 denoting a flawless alignment of the model with the data.

Cox-Snell R-squared:

Proposed by Cox and Snell in 1989, Cox-Snell R-squared serves as another metric for assessing the fitness of a logistic regression model. This modified R-squared variant evaluates how well the model conforms to the dataset. Like Nagelkerke R-squared, its scale extends from 0 to 1, with a value of 1 signifying an impeccable fit.

Hosmer-Lemeshow test:

The Hosmer-Lemeshow test, formulated by Hosmer and Lemeshow in 1980, is a statistical test gauging the goodness-of-fit of a logistic regression model. This test compares the model's calculated probabilities with the actual probabilities across different data groups. A low p-value in this test suggests an inadequate model fit to the data. These metrics prove invaluable for evaluating the accuracy and suitability of a regression model, particularly in the context of logistic regression for classification problems.

The performance of a model can be evaluated by various attributes such as accuracy and efficiency. Accuracy is calculated as the ratio of the total number of correct predictions to the total number of examples. Accuracy helps to understand how well the model performs in the general population. Efficiency refers to how quickly and efficiently the model works. This can refer to training time, prediction speed, required memory, or other parameters related to running the model. It is essential to strike a balance between accuracy and efficiency. Often, higher accuracy may require more computing resources, such as computing power, memory, or execution time. The challenge is to offset these two factors to guide model selection, development, and optimization.

Data Collection

We compiled the aggregate engagement data of students from two grades, namely Grade A and Grade B, about a particular mathematics course conducted at a specific Gymnasium. The data were extracted from the official school database, encompassing all 453 students enrolled in the course during that timeframe. It is crucial to emphasize that traditional teaching methods, involving lectures, classroom activities, homework, and exercises, were integral components of the course delivery process. Notably, no part of the course was integrated into a learning management system. The data set collected is listed in Table 1.

In the case of the first risk model, the data set was drawn from 2017 to 2019, whereas in the case of the second risk model, the data set was drawn from 2021 to 2022. It should be explained that the data set during the pandemic is not included since conventional teaching was shut down and given that the research objective is to compare the risk factors before and after the pandemic. However, there is an indirect reference to the effect of the pandemic on student final achievement (deriving from the former year's and the previous year's attendance and participation rates).

Table 1. Data collected

Data	**Measured (Time period)**
Q1: Lifetime Attendance Rate in the former School Years.	Daily
Q2: Lifetime Attendance Rate in the Previous School Year.	Daily
Q3: Percentage of participation in the prescribed written tests in the former School Years.	Monthly
Q4: Percentage of participation in the prescribed written tests in the Previous School Year.	Monthly
Final Grade (Final Exams' Grade)	Annually

Building the Risk Models

Along with the underlined data shown in Table 1, we constructed the binary variable srisk as the variable describing non-achievers. The value "0" was given for achievers, whereas the value "1" was given for non-achievers (Anagnostopoulos et al., 2020; Georgakopoulos et al., 2018; Macfayden & Dawson, 2010). The final exam's grade defined the numeric threshold for non-achievers. All variables are listed in Table 2. The first column in Table 2 shows the data collected, and the second column indicates the variable's name.

Table 2. Variables modeled

Data Description	**Variable Modeled**
Lifetime Attendance Rate in the former School Years.	Q1
Lifetime Attendance Rate in the Previous School Year.	Q2
Percentage of participation in the prescribed written tests in the former School Years.	Q3
Percentage of participation in the prescribed written tests in the Previous School Year.	Q4
Final Grade	finalgrade
Students at risk	srisk

We employed this data set in terms of a binary logistics regression analysis (Georgakopoulos et al., 2018; Macfayden & Dawson, 2010) after the final exam to develop the first risk model (before the pandemic). In our scheme, "srisk" was the dependent variable, and the other variables were the independent ones (coefficients). The "finalgrade" variable, describing the final grade (final exams' grade), was only used to determine non-achievers. It is also essential to explain that all independent variables were measured as Scale, whereas the dependent variable "srisk" was measured as Nominal. Additionally, we developed the second risk model (after the pandemic) using the same data set to examine the possibility of identical risk drivers

Results

The result of the binary logistic regression analysis conducted before the pandemic has given rise to Risk Model 1. Table 3 provides insights into the key performance characteristics of our model.

Table 3. Performance characteristics (Risk model 1)

Performance metrics

	Value
Accuracy	0.777
AUC	0.849
Sensitivity	0.882
Specificity	0.561
Precision	0.805

Table 3 highlights the assessment of our model as favorable, given its high scores across various performance metrics domains (Sensitivity: 88.2%; Accuracy: 77.7%; Precision: 80.5%). Notably, special attention is directed towards the precision metric, which signifies the intended classification rate. In our case, the model achieves a classification rate of 77.7% (refer to Table 4).

Table 4. Classification percentage (Risk model 1)

Performance Diagnostics

Confusion matrix

Observed	Predicted 0	Predicted 1	% Correct
0	83	65	56.081
1	36	269	88.197
Overall % Correct			77.704

Note. The cut-off value is set to 0.5

Analyzing Table 3, it becomes evident that the intended classification rate (precision) closely aligns with the actual classification rate (sensitivity). The great specificity percentage vouches for an accurate classification of many non-achievers. However, the same precision does not hold for achievers. Consequently, our model accurately classifies 77.7% of the cases.

It is essential to underline that our model accounts for 43 % of the risk drivers (Nagelkerke R^2), implying that approximately 57 % of the liable risk drivers are not traceable (see Table 5). It is important to stress that the range for Nagelkerke R^2 is between 0 and 1. The value "1" represents a perfect model fit (Allison, 2014; Hair et al., 2006; Smith et al., 2013). Since the Nagelkerke R^2 value for our model is not too close to 1, our model fits the data to a satisfactory but not absolute extent. Therefore, the model accounts for a specific set of risk drivers, but the possibility of new risk drivers cannot be ruled out.

Table 5. Model summary (Risk model 1)

Model	Deviance	AIC	BIC	df	X^2	p	McFadden R^2	Nagelkerke R^2	Tjur R^2	Cox & Snell R^2
H_0	572.433	574.433	578.549	452						
H_1	405.431	415.431	436.011	448	167.002	< .001	0.292	0.430	0.331	0.308

Table 6 shows the coefficients that could be included in the regression model according to the p-value.

Table 6. Coefficients (Risk model 1)

Coefficients

	Estimate	Standard Error	Odds Ratio	z	Wald Test: Wald Statistic	Wald Test: df	Wald Test: p	95% Confidence interval: Lower bound	95% Confidence interval: Upper bound
(Intercept)	0.972	0.344	2.643	2.827	7.992	1	0.005	0.298	1.646
Q1	9.471	1.375	12982.402	6.890	47.471	1	< .001	6.777	12.166
Q2	9.866	1.430	19263.576	6.897	47.572	1	< .001	7.062	12.670
Q3	-11.658	1.525	8.654×10^{-6}	-7.647	58.473	1	< .001	-14.646	-8.670
Q4	-10.112	1.507	4.060×10^{-5}	-6.711	45.037	1	< .001	-13.065	-7.159

Note. rgpav10 level '1' coded as class 1.

The factors contributing to student failure are determined by coefficients with a p-value less than or equal to 0.05. Therefore, as per Table 6, in our study, these contributing drivers are the Lifetime Attendance Rate in the former School Years (Q1), the Lifetime Attendance Rate in the Previous School Year (Q2), the Percentage of participation in the prescribed written tests in the former School Years (Q3), and the Percentage of participation in the prescribed written tests in the Previous School Year (Q4). Therefore, our regression model could be given as follows:

$Logit(srisk)= 9.471* Q1 + 9.866 *Q2 -11.658 * Q3 – 10.112 * Q4 +0.972$

Looking at the estimates in Table 6, we can deduce that if the Lifetime Attendance Rate in the former School Years (Q1) is increased, the logarithm of the probability of student failure is also increased (9.471). The same holds for the Lifetime Attendance Rate in the Previous School Year (Q2) (9.866). However, if the Percentage of participation in the prescribed written tests in the former School Years (Q3) is increased, the probability of student failure is significantly decreased (11.658). This is also true for the Percentage of participation in the prescribed written tests in the Previous

School Year (Q4) (10.112). Therefore, it is essential to point out that although all risk drivers are entered into the regression model (Q1, Q2, Q3, Q4), only Q3 and Q4 factors lead to a decrease in the probability of student failure, constituting real risk drivers. Hence, the Percentage of participation in the prescribed written tests in the former School Years (Q3), and the Percentage of participation in the prescribed written tests in the Previous School Year (Q4) appear to affect students' critical achievement before the pandemic.

The binary logistics regression outcome (after the pandemic) has led to risk model 2. Table 7 sheds light on some cardinal performance characteristics of our model.

Table 7. Performance characteristics (Risk model *2)*

Performance metrics

	Value
Accuracy	0.790
AUC	0.854
Sensitivity	0.907
Specificity	0.462
Precision	0.826

Table 7 highlights the effectiveness of our model, as it attains high scores across nearly every performance metrics domain (Sensitivity: 90.7%; Accuracy: 79%; Precision: 82.6%). Observing Table 7, it is deduced that the intended classification rate (precision) closely aligns with the actual classification rate (sensitivity). The noteworthy specificity percentage indicates an accurate classification of many non-achievers. However, the same precision is not attainable for achievers. Consequently, our model accurately classifies 79% of the cases (see Table 8).

Table 8. Classification percentage (Risk model 2)

Performance Diagnostics

Confusion matrix

	Predicted		
Observed	0	1	% Correct
0	55	64	46.218
1	31	303	90.719
Overall % Correct			79.029

Note. The cut-off value is set to 0.5

Nevertheless, it is crucial to emphasize that our model explains 42.4% of the attributable risk drivers (Nagelkerke R^2), indicating that approximately 57.6% of the potential risk drivers remain unidentified (see Table 9). It is essential to highlight that the Nagelkerke R^2 range lies between 0 and 1, where a value of "1" signifies a perfect model fit (Allison, 2014; Hair et al., 2006; Smith et al., 2013). Given that the Nagelkerke R^2 value for our model is not near 1, it indicates that our model fits the data to a satisfactory but not absolute extent. Therefore, while the model accounts for a specific set of risk factors, the possibility of undisclosed risk drivers cannot be dismissed.

Table 9. Model summary (Risk model 2)

Model	Deviance	AIC	BIC	df	X^2	p	McFadden R^2	Nagelkerke R^2	Tjur R^2	Cox & Snell R^2
H_0	521.725	523.725	527.841	452						
H_1	366.544	376.544	397.124	448	155.180	< .001	0.297	0.424	0.322	0.290

Table 10 shows the coefficients that could be included in the regression model according to the p-value:

Table 10. Coefficients (Risk model 2)

Coefficients

					Wald Test			95% Confidence interval	
	Estimate	Standard Error	Odds Ratio	z	Wald Statistic	df	p	Lower bound	Upper bound
(Intercept)	1.303	0.360	3.681	3.618	13.087	1	< .001	0.597	2.009
Q1	9.663	1.456	15722.831	6.638	44.065	1	< .001	6.810	12.516
Q2	10.263	1.556	28657.450	6.595	43.496	1	< .001	7.213	13.313
Q3	-11.730	1.592	8.051×10^{-6}	-7.369	54.295	1	< .001	-14.850	-8.610
Q4	-10.436	1.619	2.935×10^{-5}	-6.447	41.567	1	< .001	-13.609	-7.264

Note. rgpav12 level '1' coded as class 1.

The factors that have statistically significant contributions to students' failure are derived from coefficients with p-values lower or equal to 0.05. Thereby, according to Table 10, in our case, these drivers are the Lifetime Attendance Rate in the former School Years (Q1), the Lifetime Attendance Rate in the Previous School Year (Q2), the Percentage of participation in the prescribed written tests in the former School Years (Q3), and the Percentage of participation in the prescribed written tests in the Previous School Year (Q4). Therefore, our regression model could be given as follows:

Logit(srisk)= 9.663* Q1 + 10.263 *Q2 -11.730 * Q3 – 10.436 * Q4 +1.303

Looking at the estimates in Table 10, we can deduce that if the Lifetime Attendance Rate in the former School Years (Q1) is increased, the logarithm of the probability of students' failure is also increased (9.663). In parallel, the same holds for the Lifetime Attendance Rate in the Previous School Year (Q2) (10.263). However, if the Percentage of participation in the prescribed written tests in the former School Years (Q3) is increased, the probability of students' failure is significantly decreased (11.730). The same holds for the Percentage of participation in the prescribed written tests in the Previous School Year (Q4) (10.436). Therefore, it is essential to clarify that although all risk drivers are entered into the regression model (Q1, Q2, Q3, Q4), only Q3 and Q4 drivers decrease the probability of students' failure, constituting real risk drivers.

Hence, the Percentage of participation in the prescribed written tests in the former School Years (Q3), and the Percentage of participation in the prescribed written tests in the Previous School Year (Q4) appear to affect students' critical achievement after the COVID-19 pandemic.

Conclusions

Both risk models excel across nearly every performance metric domain (refer to Tables 3 and 7). Additionally, both models attain a high classification rate (refer to Tables 4 and 8). Moreover, both risk models adequately explain a substantial percentage of the identified risk drivers (refer to Tables 5 and 9). The regression outcomes for both models have demonstrated that the Percentage of participation in the prescribed written tests in the former School Years (Q3) and the Percentage of participation in the prescribed written tests in the Previous School Year (Q4) appear to affect students' critical achievement before and after the COVID-19 pandemic, denoting the indirect effect of the pandemic on students' final achievement. It is also essential to underline that in another work, pre-and post-tests appear to affect student performance in mathematics (Flores & Kaylor, 2007). At this point, it is vital to point out that the period in which the prescribed written tests were performed constituted a preparatory stage before the exams. In this spirit, the prescribed written tests acted as pre- and post-tests (Georgakopoulos et al., 2020).

Although the attendance rate in the earlier years is entered into the regression models, it appears to increase the probability of student failure. The poor attendance during the pandemic reduced the effect of these risk factors. However, the participation rate in the prescribed written tests during the pandemic attenuated such drivers (see Tables 6,10). However, more research during the pandemic should be done to generalize these findings.

In an attempt to examine the research questions' validity, we can deduce that factors related to student engagement (participation rate in the prescribed written tests) critically affected student performance before and after the pandemic. The factors that affected student final achievement before the pandemic (Q1, Q2, Q3, Q4) were identical to the ones after the pandemic. It is also essential to underline that the contribution of the prescribed written tests to the reduction of the probability of student failure was slightly increased after the pandemic, denoting that the strength of such drivers was reduced by the pandemic effect.

However, since our models fit the data sufficiently (not completely), the possibility of emerging risk drivers cannot be ruled out. Additionally, more courses are needed to accentuate the similarity of these factors.

Therefore, our research could be expanded as follows:

- Apply our risk models to more courses to rule out the possibility of new drivers.
- To generate a model to forecast non-achievers before and after the COVID-19 pandemic based on the developed risk models.
- To develop warning systems for non-achievers based on the forecast models.
- To further investigate the effect of the pandemic on students' performance, analyzing e-learning data.

In any case, the contribution of our research findings to the field is valuable since our study is based on a published risk management methodology rather than simply using a statistical technique. (Georgakopoulos et al., 2018; Vose, 2008). In parallel, our research findings could be used to mitigate the negative impact of an unsuccessful outcome in mathematics, considering the effect of the pandemic.

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Research Article

Determining secondary school mathematics teachers' errors and misconceptions in geometry[1]

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Abstract

The aim of this study is to determine the mistakes and misconceptions experienced by the teachers on the basis of the definitions and examples of geometry subjects in the error and misconception detection test prepared for elementary school mathematics teachers in secondary school geometry subjects. Errors and misconceptions experienced by teachers will open the door to mistakes and misconceptions that students will experience during the lesson. For this reason, by identifying the errors and misconceptions experienced by primary school mathematics teachers in geometry subjects, producing solutions will ensure the prevention of misconceptions. The study group of the research consists of 20 primary school mathematics teachers working in secondary schools in the center of Kars in the 2021-2022 academic year. Since the teachers who could be reached while forming the study group were included in the research, the appropriate sampling method was used. In the research, the "Error and Misconception Identification Test", which was developed by the researcher and determined by taking expert opinion, was applied. In the results of the research, it was determined that primary school mathematics teachers mostly experienced errors and misconceptions about basic geometric concepts, quadrilaterals and prisms. It was determined that the teachers did not experience the misconception that they only made mistakes in some questions.

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Introduction

Although geometry is an important branch of mathematics, it is necessary for students to see and understand some facts in the environment they live in (Doyuran, 2014). Geometry has a long history of being closely connected to the world (Jones, 2000). Geometry should be taught at an early age in terms of containing concrete shapes and facilitating mathematics teaching (Berkant and Çadırlı, 2019). It is observed that students have difficulties and difficulties in the geometry subjects taught within the scope of mathematics course, and as a result, they develop a negative attitude towards geometry. The role of the teacher in the classroom is of great importance in eliminating these negative attitudes and prejudices experienced by students. For this reason, educational environments should be supported with rich content regarding geometry, which is given to students in the early stages, and action should be taken according to the students' thinking levels (Pusey, 2003).

The fact that concepts learned in the previous class can be used again in the next class in geometry teaching emphasizes the importance of the graduality principle of geometry. Therefore, according to Kiriş (2008), it should be

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taken into consideration that each concept learned is related to the previous concept. According to Ayyıldız and Altun (2013), if these concepts are not learned correctly, the foundations of knowledge cannot be formed and connections between events cannot be established. In this context, "misconceptions" occur as a result of individuals misattributing the connections between events. According to Osoje (2015), misconception is expressed as an individual's misunderstandings and misinterpretations based on misunderstandings.

Using the expressions "misconception" and "error" together causes these two expressions to be confused with each other. Error occurs due to misconception. This means that a student who has a misconception may, as a result, exhibit incorrect approaches to some subjects (İncikabı and Kılıç, 2013). According to TDK (2011), error: wrong; It means an unintentional and unknowing mistake, flaw, mistake, error. Borasi (1987) states that errors accepted in mathematics education can be a powerful tool for diagnosing learning and that it may be possible to directly improve learning. In other words, focusing on errors provides a deep understanding of mathematical concepts. Error is defined as incorrect use of mathematical concepts and inaccuracies in operations and calculations (Erbaş et al., 2010). In this way, misconception appears as a comprehensive expression that includes error. The reason for this is that misconceptions usually manifest themselves in the mistakes made by students (Erdem and Gürbüz, 2017).

When we look at the studies conducted, we see that these studies were conducted with teacher candidates and students. In the study conducted by Köprücü (2020), 13 studies with transportation permits between 2000 and 2020 were examined. According to the data obtained, it was determined that not much work has been done on misconceptions in geometry. In the study conducted by Paksu et al. (2012), it was observed that teacher candidates' knowledge about the concept of dimension was insufficient, and they focused on different criteria such as the number of corners, number of edges, number of diagonals, and number of visible faces when deciding on the number of dimensions. In his research, Usta (2018) found that prospective teachers could not suggest solutions to detect student errors in converting volume measurement units to liquid measurement units. It was observed that the students could not make the association between volume measurements and liquid measurements. In the study conducted by Şengün and Yılmaz (2021), it was determined that there was difficulty in explaining the bisector and bisector, there were difficulties in using the ruler and protractor, and the related concepts were confused with the concept of height. In the study conducted by Erdoğan and Dur (2014), it was observed that pre-service mathematics teachers' knowledge of quadrilaterals and prototype images that they learned at the primary-secondary school level was dominant. Türnüklü and Ergin (2016) found in their research that students were far from academic definitions and mostly tried to describe the surfaces of prisms. It was observed that the students expressed the expression "it is a three-dimensional object" in different ways for the prism, and the expressions "all three-dimensional objects are prisms" caused overgeneralization. In the study conducted by Kartal and Çınar (2017), prospective teachers were more successful in questions that required knowing the mathematical definition of polygon. Although prospective teachers answered correctly whether the shapes given to them were polygons or not, the majority of them still could not define polygons completely and correctly. In Yazıcı (2019) study, prospective teachers ignored the fact that the concept of point was undefined and stated that the "pen tip" used to explain the concept of point was a point, and regarding the concept of line, the candidates expressed the line as a straight line and frequently referred to the concept of line. It was determined that they confused the expressions of truth with each other and perceived the example of truth as real truth. Çakmak et al. (2014) concluded in their study that teacher candidates mostly had difficulty in determining and defining the critical features of three-dimensional objects. As a result of their study by Bozkurt and Koç (2012), it was seen that the majority of teacher candidates could not define prism. According to the results obtained from the definitions of the concept of prism, it was seen that they were not sufficient in using mathematical language and expressing the concept that was wanted to be defined. Ulusoy (2022) stated in his study that students defined parallelism and vertical line segments by using three types of reasoning. It has been concluded that concept images shaped by prototypes and formal examples are effective in these definitions. In his study, Fischbein (1993) concluded that the concept of dimension was not developed in students and most of them thought of a point as a round object. According to this result, it was concluded that figural representations prevent the definition of concepts and create misconceptions. According to their results, Gutieerez and Jaime (1999) stated that prospective teachers had a weak concept image regarding the height in a triangle. They also concluded that although prospective teachers had formal definitions of quadrilaterals, their prototype images affected their formal concepts. Tall and Winner (1981) emphasized in their study that students tend to use concept images instead of using previous concepts in the concept learning process, and that examples should be enriched during concept learning. In his study, Blanco (2001) included his findings regarding errors in teaching and learning the basic concepts of geometry. According to the results he obtained, he stated that the students wrote the height definition of the triangle correctly, but had difficulties in drawing it. Cunningham and Roberts (2010) stated that teachers provide inadequate definitions and prototype examples when they encounter a concept they are not familiar with. Skordoulis et al. (2009), in their study on prospective mathematics teachers' understanding of the concept of size, examined the candidates' correct knowledge of the dimensions of geometric shapes and their geometric dimension measurements.

Due to the cumulative structure of mathematics and the cumulative structure of geometry, which is a branch of mathematics, errors and misconceptions occur in the learning and teaching of some concepts. The structure of geometric concepts used by the teacher in the classroom contributes to the development of students' geometric thinking skills (Erdoğan, 2006). Teachers should provide the infrastructure for the formation of conceptual knowledge instead of memorized knowledge in the classroom. Students who learn the concepts can also use the concepts they have learned on other subjects to be learned. Students who cannot achieve conceptual learning as desired have misconceptions about geometric concepts and have difficulty understanding geometric concepts. In this research, primary school mathematics teachers are asked questions about defining basic geometric concepts, how to teach a given geometric concept, drawing geometric shapes, perception of geometric dimensions, and the errors and misconceptions that occur are determined. The mistakes and misconceptions experienced by teachers will open the door to mistakes and misconceptions that students will experience during the lesson. Therefore, the most important thing should be to identify the mistakes and misconceptions that primary school mathematics teachers experience in geometry and to produce solutions. When the literature is examined, it will be possible to say that the studies were conducted with teacher candidates and students. When the thesis studies on errors and misconceptions in geometry subjects are examined, we can say that there was an intensity between 2007 and 2014 and that these studies were carried out with students (Gülkılık, 2008; Kiriş, 2008; Ay, 2014; Doyuran, 2014). For this reason, in this research, a study was conducted with primary school mathematics teachers and it is important in terms of determining the mistakes and misconceptions that teachers experience in geometry subjects. It is thought that conducting the study with primary school mathematics teachers who have spent a certain amount of time in the profession and spend time with students in the classroom environment will contribute to the literature. In addition, it is thought that determining the mistakes and misconceptions experienced by primary school mathematics teachers in geometry subjects is also important in terms of structuring the new concepts that students will learn in geometry lessons.

Problem of Study

The aim of this research is to determine the errors and misconceptions experienced by teachers based on their definitions and examples on geometry subjects in the error and misconception determination test prepared for primary school mathematics teachers in secondary school geometry subjects. For this purpose, the problem was "What are the mistakes and misconceptions that primary school mathematics teachers experience in geometry?" It was determined as. In line with the research problem the sub-problems are as follows:

- What kind of mistakes do primary school mathematics teachers have in secondary school geometry subjects?
- What are the misconceptions of primary school mathematics teachers about secondary school geometry?

Method

Research Model

The aim of the study was to identify the mistakes and misconceptions experienced by primary school mathematics teachers in secondary school geometry subjects. Therefore, this study is a case study model, one of the qualitative research methods. Case studies, also known as case studies, are accepted as a method in which one or more events, environments, situations or groups are examined in depth (Büyüköztürk et al., 2020). This study, which was conducted to identify the errors and misconceptions experienced by primary school mathematics teachers in geometry subjects, categorize them, explain them with their reasons and make suggestions, constitutes an example of the case study model, one of the qualitative research methods.

Study Group

The study group of the research consists of 20 primary school mathematics teachers working in secondary schools in Kars center and districts in the 2021-2022 academic year. Since the teachers who could be reached while determining the study group were included in the study, the appropriate sampling method, one of the non-random sampling methods, was used. The appropriate sampling method is defined as selecting the study group from easily accessible and applicable respondents (Büyüköztürk et al., 2020).

Data Collection and Analysis

The analysis of the data collected in this research was done with content analysis, one of the qualitative analysis types. Content analysis is a systematic technique in which some words of the study are summarized into smaller categories by coding within the framework of certain rules (Büyüköztürk et al., 2020). With content analysis, researchers make interpretations of the message in the text by determining and analyzing the meanings and relationships of words and concepts (Büyüköztürk et al., 2020). Inferences were made by determining the errors and misconceptions experienced by primary school mathematics teachers in secondary school geometry subjects, examining the definitions given, and subjecting them to content analysis along with the answers obtained from the teachers' opinions.

By conducting a literature review, criteria were created to identify errors and misconceptions. Deficiencies in expressions and incorrect use of words and terms determined after the teachers' definitions and interviews were treated as errors. The definitions and explanations made by the teachers and the examples they gave were examined together. Confusion of concepts on topics that are related to each other, inability to associate them with examples, having incorrect information, different answers that are not related to the question, prototype definitions, answers that create a concept image, and answers that appear to have concepts that do not match scientific concepts are examined in the misconception category.

Procedure

The test has been prepared in accordance with the objectives determined to address all achievements in secondary school geometry subjects. While determining the outcomes of the questions in the "Errors and Misconceptions Identification Test", care was taken to include topics that addressed geometry subjects at the secondary school level.

Table 1. Questions and learning outcomes in the error and misconception identification test

1.	a) Define the concept of "point". Explain by giving an example. b) Define the concept of "Dimension". Explain by giving an example. b1) Define the concepts of two and three dimensions. Explain by giving an example.	*M.5.2.1.2. It expresses the position of a point relative to another point using direction and units.*
2.	Can you define the concepts of line, line segment and ray? Express with examples.	*M.5.2.1.1. Explains line, line segment, ray and shows it with symbols.*
3.	Define the concept of steepness. Explain by giving an example.	*M.5.2.1.5. Draws a perpendicular to a line from a point on or outside it.*
4.	Describe the types of triangles. Express with examples.	*M.5.2.1.5. Draws a perpendicular to a line from a point on or outside it.*
5.	Define the concept of quadrilateral. Explain by drawing a figure.	*M.5.2.2.3. Determines and draws the basic elements of rectangle, parallelogram, rhombus and trapezoid*
6.	a) Can you prove the sum of the interior angles of a triangle? b Can you prove the area of a triangle?	*M.5.2.2.4. Determines the sum of the measures of the interior angles of triangles and quadrilaterals and finds the angle that is not given.* *M.6.3.2.1. Creates the area relationship of the triangle and solves related problems.*
7.	a) Explain the difference between a circle and a circle. Express with an example. b) Explain the concepts of circle and perimeter-area in a circle.	*M.6.3.3.3. Solve problems that require calculating the length of a circle given its diameter or Radius* *M.7.3.3.3. Calculates the area of the circle and circle segment.*
8.	How would you describe the transition from liquid measurements to volume measurements? Express with examples	*M.6.3.5.2. Relates liquid measurement units to volume measurement units.*
9.	a) How do you express that the angle goes to infinity? Express with examples. b) Express the stages of drawing the bisector of an angle. Explain in sentences by drawing figures c) Express the steps of drawing a triangle. Explain in sentences by drawing figures.	*M.6.3.1.1. She knows that the angle is formed by two rays with the same starting point and represents it with a symbol.* *M.7.3.1.1. Determines the bisector by dividing an angle into two equal angles.* *M.8.3.1.4. Draws a triangle given the dimensions of a sufficient number of elements.*
10.	 How do you show the sum of interior angles in polygons without using mathematical relations?	*M.7.3.2.2. Determines the diagonals, interior and exterior angles of polygons; Calculates the sum of the measurements of the interior angles and exterior angles.*
11.	a) Is a cube a prism? Explain with reasons. b) How do you name prisms? Explain with example.	*M.8.3.4.1. Recognizes right prisms, determines their basic elements, constructs them and draws their expansion.*
12.	a) Describe the difference between congruence and similarity in triangles. Express with an example. b) While explaining the concepts of congruence and similarity in triangles, what are the gains you convey to the students regarding the subject of ratio and proportion? Express it with explanation	*M.8.3.3.1. Relates congruence and similarity, determines the side and angle relationships of congruent and similar shapes..*

The researcher included achievements that address secondary school geometry subjects and include subjects at all grade levels. The content validity of the prepared error and misconception detection test was ensured by taking the opinions of two faculty members who are experts in the field of geometry. Then, a pilot application was conducted and an error and misconception detection test was applied to eight graduate students. In practice, it was observed that students answered the test within 45 minutes. Therefore, the application time of the test was determined as 45 minutes. After the pilot application, the error and misconception detection test was applied to twenty primary school mathematics teachers and data was collected.

Results

In this part of the research, the findings and comments obtained from the error and misconception test prepared regarding secondary school geometry subjects are included. In addition, the findings and comments of the interview held after the analysis are also included in this section.

Table 2. Define the concept of *point* frequency and percentage values regarding the distribution of teacher answers and errors-misconceptions regarding the question "explain with example"

Answers		**f**	**%**
Academically accepted answer	Point; is a non-existent, dimensionless, abstract geometric term.	5	23,80
Misconceptions	The mark left by the pen on the paper	15	71,42
	Multiplication sign	1	4,76
	Total	21	100

When the answers given by primary school mathematics teachers to the question about defining the concept of "dot" and giving examples are examined in Table 2, it is seen that 23.80% gave the academically correct answer and 76.18% had various misconceptions. According to the interviews conducted with primary school mathematics teachers after the analysis, it was seen that the teachers did not make any mistakes in this question. After analyzing the answers given by the teachers who had misconceptions, an interview was conducted about the concept of "dot". When the answers given and the data obtained after the interview were brought together, it was determined that primary school mathematics teachers used the definition of "the mark left by the pen on the paper" in their lessons for the concept of "point". This definition for the concept of "point" shows that teachers have a prototype or concept image. According to the answer to this question, which includes the concept image rather than the concept definition, it is seen that the majority of teachers have misconceptions about the concept of "point". Some answers obtained from primary school mathematics teachers are given below;

> "The mark left by the pen on the paper".... (S1).
> "The shape that appears when we put the tip of the pen on the paper, the shape that appears when we touch it".....S3).
> "A dot is the mark left by a pen on a surface. Used instead of multiplication sign in mathematics"....(S11).
> "A geometric concept that has no width, length or height is called"....(S14).

After the interview with primary school mathematics teachers who were thought to have misconceptions, one of the teachers stated, "I explain the concept of point to the student in this way to concretize it." Another teacher answered: "I use this definition in my lessons, and to elaborate, I state that the dot is the smallest building block." Another teacher said, "In mathematics class, students use "." instead of "x" as the multiplication sign. They use the sign. He responded to the interview by saying, "I can use this when explaining the concept of point." Another teacher who had a misconception stated that he defined a point in his lessons as "the mark left by the pen on the paper".

Conclusion and Discussion

This research covers the examination of the mistakes and misconceptions experienced by primary school mathematics teachers regarding secondary school geometry subjects. Suggestions regarding the results are also included under this heading. “What are the mistakes and misconceptions that primary school mathematics teachers experience in geometry?” problem and "What kind of mistakes do primary school mathematics teachers have in secondary school geometry?" and “What kind of misconceptions do primary school mathematics teachers have about secondary school geometry?” The results of the sub-problems are given in this section.

When the results of the first sub-problem are examined, the primary school mathematics teachers' deficiencies in expression, verbal errors, not being able to read the question correctly, using different expressions than the desired answer in the question, questions left blank, lack of information, giving relations, including information other than what is requested in the question are evaluated under the error heading. It was observed that primary school mathematics teachers had difficulty in conceptually defining the answers they gave to the question about the cube being a prism, they contained incomplete expressions and they started from specialized situations. The answers of the teachers who included these statements were evaluated under the heading of errors. Lack of expression and use of mathematical language in the conceptual definition of prisms (Bozkurt and Koç, 2012); Using some specialized situations and thinking that only square and rectangular prisms have the property of being prisms (Türnüklü and Ergin, 2016) have shown that teachers made mistakes.

When we look at the findings regarding the second sub-problem, the answers that primary school mathematics teachers gave personalized and bookish definitions, far from academic definitions, and especially expressions containing prototypes and concept images, were examined under the title of misconception. Through the interviews, it was clarified that the answers given by the teachers who had misconceptions were misconceptions.

According to the results obtained from the findings, it was seen that primary school mathematics teachers mentioned the prototype structure in their answers regarding the definition of the concept of "point". It was observed that 71.42% of the teachers could not make a conceptual definition of the point with the answer "the mark left by the pen on the paper". As a result of the interviews, it was determined that this definition was used in the lessons. In the activity about comparing the size and weight of points in two different drawings given by Fischbein (1993), students stated that the point formed by the line formed by crossing many lines is larger. According to the findings, Fischbein's (1993) study will be exemplary considering that teachers' failure to academically define the "point" in lessons may lead to size-related problems in students. It has been stated that the majority of primary school mathematics teachers ignore that the concept of point is undefined and assume it to be a "pen tip" (Doyuran, 2014; Yazıcı, 2019).

In defining the concepts of "line, line segment, ray", it was observed that primary school mathematics teachers included the expressions length and straight line for the concepts of "line" and "ray". Yazıcı (2019) stated in his study that prospective teachers frequently used the expression "straight line" regarding the concept of "right". It would be possible to say that teachers mostly make mistakes in the concepts of "line" (Ubuz, 1999; Yazıcı, 2019) and "ray". According to the findings, it was observed that teachers' possession of prototype structures related to the concept of "line segment" led them to misconceptions. Considering the statement mentioned by Yazıcı (2019) that teacher candidates are at least mistaken in the concept of "line segment", it can be seen that there is a difference from the study in this regard. It has been observed that teachers experience misconceptions due to the prototype structures they have (Gutieerez and Jaime, 1999; Doyuran, 2014; Ulusoy, 2022).

When we look at the studies conducted on geometry misconceptions, it was seen that polygons and quadrilaterals were the most common topics in the subject distribution between 2000 and 2020 (Köprücü, 2020). In this study, it was observed that the teachers were successful in providing the desired explanations about the interior angles of polygons and there were no teachers who had misconceptions. When a similar study was conducted by Kartal and Çınar (2017), it was seen that the participants were successful in knowing the definition of polygons. It would be possible to say that teachers have concept images regarding the concept of "Quadray". Teachers who cannot reach the correct definition academically have difficulty in giving conceptual definitions to students in their lessons. The reasons behind the non-existence of the concept of "quadrangle" extend to basic geometric concepts. Considering that teachers make definitions such as combinations of points and adding line segments end to end, this supports this (Erdoğan and Dur, 2014; Yurtyapan and Karataş, 2020).

Within the scope of the angle concept, it has been determined that teachers teach in their lessons by dividing the "angle into two equal parts" for drawing the "bisector" and they confirmed this data during the interviews. Blanco (2001) states in his study that there are difficulties in understanding the auxiliary elements in the triangle. In the study conducted by Şengün and Yılmaz (2021), it was determined that students had difficulty in explaining the concept of bisector.

It has been stated that teachers use prototype expressions in teaching the concept of "Prism" and include these expressions in their lessons. Teachers are mistaken in thinking that the side faces of the prism concept consist only of rectangles. This is where teachers made mistakes in the definition of "cube". Because teachers accept the side faces only as rectangles and also think that the condition of being a prism depends on this. Çakmak et al., (2014) stated that there are difficulties in determining the critical properties of three-dimensional objects. In this study, it was seen that explanations were made by ignoring some critical features about the "cube". Considering that the concept of "cube" is a special prism, it has also been observed that teachers are inadequate in defining prism properties. This result is similar to the study conducted by Bozkurt and Koç (2012).

Looking at the results, it can be seen that primary school mathematics teachers mostly make mistakes and misconceptions in basic geometric concepts, quadrilaterals and prisms. According to this result, it turns out that teachers' misconceptions about basic geometric concepts affect their subsequent learning. The reason for this situation is that geometric concepts (point, line segment, line, ray, angle, plane, etc.) are the basis of the subjects of quadrilaterals and prisms. At the same time, another result obtained from this research showed that teachers constantly use concept images and prototype structures in their lessons. Tall and Winner (1981) state that students use concept images instead of using concepts in their concept learning processes. In other words, it is thought that the reasons why students use classical, bookish definitions may be due to teachers using prototype expressions of concepts in their teaching processes. For this reason, it may be inevitable that the misconceptions that teachers will experience due to their concept images will also create problems in students' learning of concepts. It has been stated in many studies that prototype expressions are frequently used in teaching concepts in geometry subjects (Tall and Winner, 1981; Mason, 1989; Gutieerez and Jaime, 1999; Cunningham and Roberts, 2010; Erdoğan and Dur, 2014; Doyuran, 2014; Ulusoy, 2022).

Recommendations

- In this research, the mistakes and misconceptions experienced by primary school mathematics teachers in secondary school geometry subjects were investigated and questions were prepared to cover all subjects. As a result, important misconceptions have been reached on some subjects rather than all subjects, and these issues need to be examined in depth.
- It is seen that the misconceptions experienced by primary school mathematics teachers on basic geometric concepts are reflected in the teaching of other subjects and misconceptions occur in these subjects as well. For this reason, it is thought that conducting studies on basic geometric concepts may be effective.
- In this research, errors and misconceptions were identified, but no analysis was made for these errors and misconceptions. For this reason, it is important to conduct a comprehensive study on secondary school geometry subjects together with teachers and students in order to provide information on how to resolve the errors and misconceptions that will be obtained.

- According to the errors and misconceptions obtained from the research, the prototype structures that teachers have should be taken into consideration. Accordingly, attention should be paid to the contents of the textbooks used by teachers in their lessons and expressions containing concept images should be reviewed.

Limitations of Study

It is limited to the 2021-2022 academic year. This research is limited to official public secondary schools in Kars province.This research is limited to primary school mathematics teachers. The secondary school mathematics program is limited to all subjects in the field of geometry.

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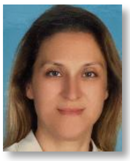

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Research Article

Perceived teacher support on student engagement through self-efficacy as a mediator in elementary school students' mathematics lesson

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Abstract

This study aims to determine the effect of Teacher Support on student engagement through self-efficacy as a mediator in the mathematics learning process of elementary school students in Surabaya, Indonesia. The sample used 181 students in grades four to five who took mathematics classes at Elementary School. The data collection used included scales of Teacher Support, self-efficacy, and student engagement using a Likert Scale. The Student Engagement Scale consists of 16 valid items with a reliability coefficient of .856. The Teacher Support Scale consists of 10 valid items with a reliability coefficient of .743. The Self-efficacy Scale consists of 17 valid items with a reliability coefficient of .885. The data analysis technique used path analysis. and Sobel test. The results of the Sobel analysis show a t-count value of 3.192 > 1.97, which explains that t-count is greater than t-table. This shows that self-efficacy plays a significant role as a mediator in the influence of teacher support on student engagement in mathematics learning.

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Introduction

According to the Organization for Economic Cooperation and Development's (OECD) Program for International Student Assessment (PISA) study of 15-year-old students in 2015, Indonesian students ranked 63rd out of 72 nations in terms of their proficiency in mathematics (Giwati, 2018). The TIMSS results in 2015 received the latest results, namely that Indonesia was ranked 44th out of 49 countries (Nizam, 2016). The results of observations in various elementary schools in grades IV and V in several cities on Java found that there are still many students who do not pay attention to the teacher when the learning process is taking place. Students quickly feel bored when studying mathematics, and they are not interested in learning mathematics because they view mathematics as an abstract field of study. There are students who don't seem interested in learning and prefer telling stories and playing with friends; there are students who don't pay attention, chat with friends, go in and out of class, don't do assignments, etc. From the results of the analysis of daily test scores, it shows an average score of 56.66 and classical completeness of 44.44%. These learning outcomes are low and unsatisfactory.

In facing everyday life, all children will face various things that require organizing and using information in a competitive, uncertain and constantly changing environment, therefore children must be able to think rationally, analytically, methodically, critically, creatively and cooperatively. Therefore, Nahdi (2017) believes that mathematics

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teaching should start in elementary school. This is because mathematics teaches logical, analytical and systematic thinking skills

Mathematics achievement is influenced by the extent to which students are engaged during the lesson. According to Bergdahl et al. (2020), Martin and Bolliger (2018) the strong involvement of students in learning activities both within and outside the classroom eventually has an impact on learning outcomes. This idea goes beyond just explaining students' interests or willingness to learn, explaining how they engage psychologically in order to understand numerous concepts in education in an efficient and useful manner (Poondej & Lerdpornkulrat, 2016; Zambak & Magiera, 2018). According to D'Mello and colleagues (2017), student engagement actively helps learning activities. According to Fredricks (2015), students who are increasingly focused on learning or engaged in learning can overcome the problems of low learning achievement, high levels of student boredom, and alienation and even reduce the high dropout rate.

Student Engagement

According to earlier studies Fredricks (2011), Afzal and Crawford (2022), student engagement has three dimensions: behavioral engagement, emotional engagement, and cognitive engagement. According to Reeve and Tseng (2011), behavioral engagement states that student involvement in learning activities is effort, persistence and attention in the learning process. Emotional engagement, which can be seen by the enthusiasm and interest of students, the absence of anger, boredom and anxiety. Cognitive engagement describes cognitive engagement as the use of self-regulation and advanced and in-depth learning techniques in the process of learning activities carried out by students.

According to the research findings, the interaction of specific student needs and contex is a key element in fostering student engagement (Reyes, et al., 2012; Taylor & Parsons, 2011). The environment and contex in which learning takes place affect student's engagement in the teaching process. The surroundings "cannot be separated from the student's engagement," according to Fredricks and McColskey (2012). McMahon and Zyngier (2009) treat student engagement in their study as a significant social signal that motivates teachers to encourage students in return. To sway pupils' behavior, the teacher uses a variety of social messages related to his or her teaching approach. These messages are conveyed by the teacher using a range of verbal and nonverbal cues. Depending on the situation, this may entail encouraging the students to continue working on a particular activity in the same manner they did at first, or it may entail responding to inquiries or general student behavior.

The self-system model of motivational growth is mentioned in the many viewpoints presented above (Connell & Wellborn, 1991; Skinner et al., 2008). The self-determination theory was the foundation for this approach (Ryan & Deci, 2000). This theoretical framework helps us understand how social context influences students' self-system processes, which in turn affects their engagement and achievement. According to the idea, competence, autonomy, and relatedness—three fundamental human needs—form the context for the development of self-system processes (Connell & Wellborn, 1991).

Teacher Support

The social context factor in the classroom is the relationship between teacher and student, student and student. Teachers' social support is a form of fulfilling students' needs for relatedness, but it also has an impact on other aspects. Connell and Wellborn (1991) said that self-system processes including competence, autonomy, and relatedness lead to engagement or disaffection. In specifically, the paradigm holds that engagement takes place when psychological needs are addressed and is reflected in cognition, mood, and behavior. According to studies, pupils who have kind and encouraging connections with their classmates report having more positive academic attitudes and values as well as higher levels of school satisfaction. These students are also more academically engaged (Marks, 2000). The research results of Xu, et.al. (2023) shows that there is a relationship between perceived teacher support and student engagement ($r_{xy} = .249$, $p<.05$). Chong, et al. (2018) said that teacher support is a form of support that influences students so they can be actively involved in class. Brewster & Bowen (2004) say that the teacher's attitudes and behavior shown to students will influence how happy or bored students are with school. The relationship between teachers and students can develop academic values, maintain student involvement in the long term, and shape students' self-identity as learners (McHugh et al., 2013).

Other self-system activities, such self-efficacy, which denotes confidence in one's capacity to bring about a desired result (Bandura, 1997). According to Bandura, self-efficacy is an individual's belief in their ability to do something and produce things that are in accordance with their initial goals. Bandura (1997) and Schunk (1991) explained that self-efficacy has been linked to the amount of effort and willingness to stick with projects. When they possess the necessary skills, those with strong efficacy beliefs are more likely to put out effort in the face of hardship and stick with a task. As a result, students who had higher self-efficacy views were considerably more likely to be cognitively engaged than students who had lower self-efficacy beliefs. Furthermore, high self-efficacy beliefs were linked to a gradual rise in the use of meta-cognitive techniques over time, as well as elaboration and organizational strategies for deeper processing (Linnenbrink & Pintrich, 2003). This is supported by the results of Qudsyi's research (2020) it shows that self-efficacy is the strongest variable in predicting student engagement.

Self-efficacy

In explaining self-efficacy, Bandura (1997) suggests that one source of effectiveness is verbal persuasion from other people. Teacher support is included in the source of self-efficacy, namely verbal persuasion that comes from the social environment. According to Liu et al. (2001), perceived teacher support is the idea that students have that their teachers care about them and will help them if they need it by providing them with academic, emotional, and competence support. The research results show children who experience more teacher support in math classes have more positive attitudes and have higher levels of self-efficacy when it comes to mastering math (Rice et al., 2013). However, students are less likely to convert their academic interests into goals and activities when the learning environment is undersupport, which lowers their academic self-efficacy (Olani et al., 2010). Numerous research have demonstrated that academic self-efficacy can be favorably predicted by perceived teacher support (Liu et al., 2021). This is supported by the research results of Ren, at al. (2022) showed that teacher support positively predicted self-efficacy ($\beta = 0.52$, $p < 0.001$).

Problem of Study and Hypothesis

Based on these perspectives, the authors deal with engagement. Teacher support will have a greater impact on student engagement only if self-efficacy is a mediator. The theoretical model of student engagement in this research is listed below. Therefore, the research hypothesis is:

- there is a simultaneous direct effect of teacher support and self-efficacy on student engagement
- there is a direct effect of teacher support on self-efficacy
- there is an influence of teacher support on student engagement through self-efficacy as a mediator.

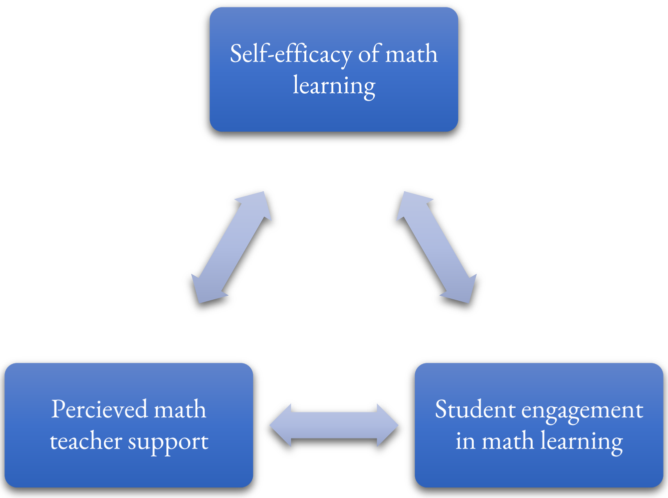

Figure 1. Theoretical model for student engagement in math learning

Method

Research Model

The research was designed with quantitative. According to Creswell (2003), quantitative research uses experimental and survey research methods and collects data using predetermined instruments to provide statistical data. Quantitative research can produce results that are prescriptive, explicative, and confirmatory. In this research, a quantitative method was used to confirm the role model of self-efficacy as a mediator on the influence of perceived teacher support on student engagement.

Participants

This researcher involved a total sample of 181 students in four elementary schools with the characteristics of fourth to fifth grade students who attended math classes. Purposive sampling method was used to determine the participants of the study. The four elementary schools involved in this research are private elementary school of Pancasila 45, private elementary school of Muhammadiyah 12, state elementary school of Tembok Dukuh 1, and state elementary school of Bubutan VIII at Surabaya. Number of respondents by school and class can see on table 1.

Table 1. Participants structures

School	Class	N	%
Private Elementary School of Pancasila 45, Surabaya	4th grade	18	10,5%
	5th grade	19	10,4%
Private Elementary School of Muhammadiyah 12, Surabaya	4th grade	27	14,9%
	5th grade	29	16%
State Elementary School of Tembok Dukuh 1, Surabaya	4th grade	27	14,9%
	5th grade	30	16,5%
State Elementary Shool of Bubutan VIII, Surabaya	4th grade	16	8,8%
	5th grade	15	8%
Total		181	100%

The measuring instruments for this research use the Student Engagement Scale based on aspects compiled by Fredricks (2011), the Self-Efficacy Scale based on aspects compiled by Bandura (1997), and the Teacher Support Scale compiled based on aspects of Chen (2005). The three scales are in Likert form with four answer choices: Student Involvement Scale (21 items, $\alpha = 0.856$), Self-Efficacy Scale (17 items, $\alpha = 0.885$), Teacher Support Scale (10 items, $\alpha = 0.743$). Data analysis to prove the hypothesis using regression analysis.

Data Collection and Procedure

Validity analysis uses a classic approach by correlating the total item score with the total score of the measuring instrument. Reliability analysis uses Cronbach's alpha formula with a coefficient limit of > 0.6 which is declared reliable. The instrument for measuring student engagement variables was prepared by researchers based on Fredricks' (2011) theory that there are three dimensions, namely behavioral engagement, emotional engagement, and cognitive engagement, and arranged based on a Likert scale of 21 items. The validity test result was obtained for 16 valid items. The reliability test obtained an alpha coefficient of .856.

The teacher support variable measuring tool was prepared by researchers based on the opinion of Chen (2005) that there are three dimensions, namely cognitive support, emotional support, and instrumental support, and is arranged based on a Likert scale of 22 items. The validity test result was obtained from 10 valid items. The reliability test obtained an alpha coefficient of .740.

The self-efficacy variable measuring instrument was prepared by researchers based on the opinion of Bandura (2001) that there are three dimensions, namely level, strength, and general, and is prepared based on a Likert scale of 19 items. The validity test results obtained 17 valid items. The reliability test obtained an alpha coefficient of .885.

Results

Hypothesis testing in the research was carried out by path analysis and then using mediation analysis using the sobel test. The Sobel test is used with the aim of finding out the value of the mediator. The results in this study are presented below.

Direct Effect Teacher Support on Self-Efficacy

The first, we analyzed direct effect of teacher support on self-efficacy. Direct effect of teacher support on self-efficacy can see on table 2.

Table 2. Direct effect teacher support to self-efficacy

Coefficients[a]						
Between Variables	**Model**	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
Teacher Support → Self-Efficacy	(Constant)	17.909	4.247		4.217	.000
	Teacher Support	1.002	.133	.491	7.536	.000

Based on table 2, it can be concluded that t = 7.536 and $p < 0.05$, that there is a significant influence of teacher support on self. efficacy and magnitude of influence .491

Direct Effect Teacher Support and Self Efficacy on Student Engagement

The second, we analyzed direct effect of teacher support and self-efficacy on student engagement. Direct effect of teacher support and self-efficacy on student engagement can see on table 3.

Table 3. Multiple regression analysis test results

Coefficients[a]						
Between Variables	**Model**	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
Teacher Support → Student Engagement	(Constant)	26.010	3.679		7.071	.000
Self-efficacy → Student Engagement	Teacher Support	.057	.126	.033	.455	.650
	Self-efficacy	.441	.062	.519	7.144	.000

Based on table 3, the results of the multiple regression analysis are the effect of teacher support on student engagement was obtained with a value of t=.455 and $p > .05$, so it can be concluded that there is no direct effect of teacher support on student engagement, with an effect size of .033. The effect of self-efficacy on student engagement obtained t = 7.144 and $p < 0.05$. It can be concluded that there is a significant influence of self-efficacy on student engagement, and the magnitude of the influence on student engagement = .519

Indirect Effect Teacher Support on Student Engagement and Self Efficacy as Mediator

The third, testing the indirect effect of teacher support on student engagement through the mediator self-efficacy obtained the following results:

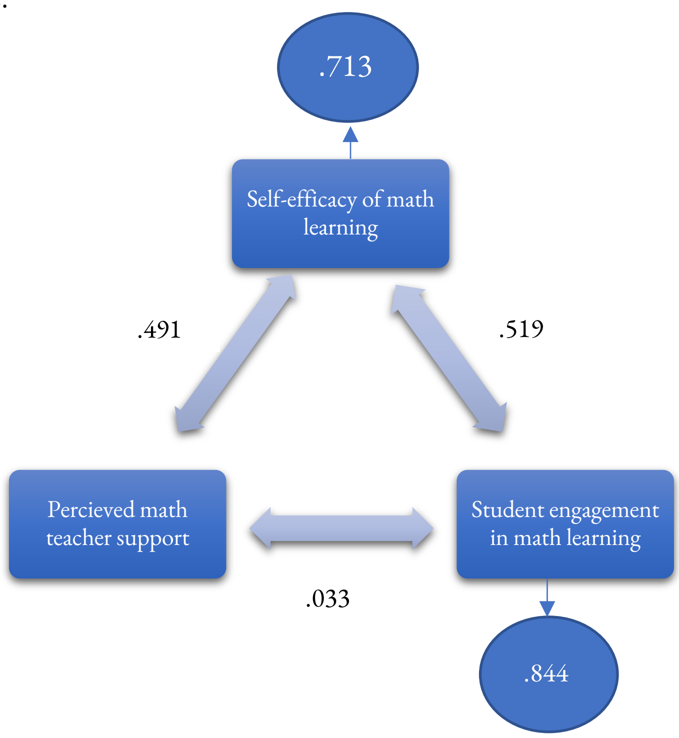

Figure 3. Student engagement model in math learning

The magnitude of the mediator's influence can be calculated by calculating the coefficient of the direct influence of teacher support multiplied by the coefficient of the direct influence of self-efficacy on student engagement, which is obtained as .491 x .519 = .2548. The magnitude of the influence of teacher support on student engagement after entering the mediator variable is .2548, which means it is greater than the direct influence of teacher support on student engagement (.2548 >.033). The Sobel test was used to determine the role of the mediator, namely, whether self-efficacy acts as a mediator. The t-count result is 3.1925, while the t-table is =1.97. Thus, it can be concluded that t-count > t-table, which means that self-efficacy significantly plays a full mediating role in the influence of teacher support on student engagement.

Discussion and Conclusion

This research examines the influence of teacher support on student engagement through self-efficacy as a mediator among elementary school students in grades 4-5. The results of the analysis show that there is no significant influence of teacher support on student engagement. Aljareh and Shindel (2020) report that proper student-teacher interactions stimulate learners to participate in class activities as they foster an emotionally favorable and supportive classroom environment. Meanwhile, student engagement concerns not only emotional aspects but also behavioral and cognitive aspects (Fredericks, 2011). Teachers' influence is framed within a theoretical framework of self-determination as a contextual factor; the external environment can heighten intrinsic motivation, promote the internalization of extrinsic motivation, and sustain engagement by meeting three fundamental psychological needs: autonomy, competence, and belonging (Deci & Ryan, 1985). According to the notion of self-determination, teacher assistance only affects relatedness requirements and possibly behavioral engagement while having no impact on the cognitive component of involvement. This explains why students' perceptions of teacher support do not enough affect their involvement.

However, the analysis's findings indicate that teacher support has a direct impact on students' engagement when self-efficacy is taken into account as a mediator. Self-efficacy, according to Bandura, is the conviction that one can accomplish goals and produce results that are consistent with those aims. Bandura (1997) and Schunk (1991) explained that self-efficacy has been linked to the amount of effort and willingness to stick with projects. Self-efficacy is considered to be a type of motivating belief that will affect all facets of student engagement. Students' behavioral engagement is favorably correlated with their self-efficacy views. Students who believe they can complete the assignment successfully are far more likely to work hard, persevere, and seek assistance in a flexible way (behavior engagement). Students who lack self-assurance are far less likely to put in a strong effort, are more likely to give up easily at the first sign of difficulties, or will attempt to complete the task without learning or mastering it with the assistance of others. Similarly, Linnenbrink and Pintrich (2003) claimed that when students feel confident in their ability to complete mathematical tasks, it will motivate them to be cognitively engaged, specifically through the use of deeper processing strategies like elaboration and organization strategies as well as meta-cognitive strategies. Wright and Mischel (1992) find that emotions can affect self-efficacy. According to Harter (1992), students who have high levels of self-efficacy are more likely to feel proud or happy when they succeed in their academic endeavors. In contrast, people who have low levels of self-efficacy frequently feel anxious or depressed (Pintrich, Roeser, & De Groot, 1994). These encouraging feelings will encourage students to participate in their studies.

Student engagement during learning is an important factor because it will determine the success of students in mastering subject matter (Ashwin,& McVitty, 2015), especially mathematics. To be able to engage in mathematics lessons is not only an emotional factor, but students' cognitive factors are also very determining. This result is shown in the model in this research: that the self-efficacy factor has a very significant influence on student engagement and plays a full role as a mediator of the influence of teacher support on student engagement. This is supported by the results of research by Parameswara et al. (2022) showing that cognitive reconstruction, namely changing thoughts that say "I can't" to "I can", can reduce students' anxiety. When students no longer experience anxiety, they will engage in the lesson material. Such cognitive reconstruction can also change negative self-efficacy into more positive self-efficacy.

Recommendations

The results of this research indicate that there is an influence of teacher support on student engagement in elementary school students' mathematics lessons through self-efficacy as a mediator. Based on the results of this research, it is recommended that teachers be able to strengthen students' self-efficacy abilities related to mathematics lessons and continue to provide cognitive, emotional, and instrumental support. School principals to provide training to teachers on learning models that not only transmit mathematical knowledge but can also increase students' self-efficacy. This is important because self-efficacy abilities will contribute to increasing student engagement in mathematics instruction. If the student's engagement in mathematics learning is high, it will have an impact on high mathematics achievement as well.

Limitations of Study

The limitation of this research is that the research subjects were students in grades four to five, although the measuring instruments for this research have been prepared according to theoretical aspects and in language that can be understood by elementary school-age children in grades four to six, so it is recommended for future researchers to take samples from the same class. In addition, research was conducted that described the influence of each teacher's support on student engagement.

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Research Article

Implementation of TPACK-based integrated innovative learning design in linear algebra course

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Abstract

The purpose of this study was to describe the results of implementing an integrated innovative learning design based on Technological, Pedagogical, and Content Knowledges (TPACK) in Linear Algebra courses. This research is an explorative, descriptive research of which analysis is carried out through implementation on students of the Mathematics Education study program at Faculty of Teacher Training and Education University of Mataram who take Linear Algebra course. The study involved 58 students spread across two classes, namely class D, with as many as 31 students, and class E, with as many as 27 students. The research instrument used was a linear algebra problem-solving test. The results showed that the resulting integrated innovative learning design has not been effectively implemented in linear algebra lectures. From the category of ability levels, the characteristics of each can be described, namely subjects in the Very Poor category. Participants understanding is still mechanical, merely applying the methods they remember, and the results are also less precise. Subjects in the Less category can use memorized methods correctly but could not develop other methods or cases. Subjects in the Fair category can try to solve problems with other rules/methods even though neither result is correct. Subjects in the Good category can solve problems with other rules but need more confidence in determining the correct answer. Meanwhile, subjects in the Very Good category can solve problems with complete confidence in determining the correct answer without a doubt. Based on these results, it is hoped that an TPACK-based integrated innovative learning design can be developed even better in the future.

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Introduction

According to the Organization for Economic Cooperation and Development's (OECD) Program for International Some problems in linear algebra lectures were identified through observations during linear algebra lectures and previous studies. Students usually do not encounter difficulties when given calculation or procedural problems, even if the problem is complex, such as the Gram-Schimdt process. However, most students have difficulty solving conceptual problems, even if the problem is not complex, such as proving a simple theorem.

Previous research in college on LA courses has been conducted by Lapp et al. (2010), which results showed that students find it more difficult to make connections between concepts, such as eigenvalues and eigenvectors, from other

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conceptual parts, such as bases and dimensions. Previous research by Arjudin et al. (2019) showed that students' ability to solve linear algebra problems still tends to be low. The lack of problem-solving partly relates to students' incomplete mathematical connection ability. Incomplete connections occur when the connected components are in the form of incorrect concepts/ideas, the connection path can be wrong/inappropriate, or the connection results can be incorrect. It indicates that there are problems in Linear Algebra courses that need to be researched to get a solution so that they can improve students' problem-solving skill, especially in Linear Algebra courses.

Several research have conducted related to problem-solving. For instance, a research conducted by Socas and Hernandez (2013) suggested that problem-solving is considered as an integral part of mathematics and is explained in terms of problem-solving, building relationships between concepts, operations, and processes implicit in mathematical activities. Meanwhile, Carlson and Bloom (2005) produced a multidimensional problem-solving framework with four stages: orientation, planning, execution, and review.

Improving students' thinking skills will certainly be difficult to achieve without being integrated into an innovative learning design. One of the higher-order thinking processes can be formed in a meaningful learning process. Knapp et al. (1995) suggested that the advantages of meaning-oriented learning that have been identified are: (a) expanding the range of mathematical content learned to give the students a sense of the breadth of mathematics and its applications; (b) emphasizing connections between mathematical ideas; (c) exploring mathematics embedded in rich "real life" situations; (d) encouraging students to find multiple solutions and focusing students' attention on the connections between the solution processes used, and (e) creating multiple representations of ideas (e.g., pictures and physical objects).

In the learning system, there are several terms that are components of the learning structure, including learning models, learning approaches, learning strategies, learning methods, and learning techniques. Developing a learning design cannot be separated from these components.

A learning model is a conceptual pattern that describes a systematic procedure drawn from start to finish, typically presented by the teacher in organizing learning experiences to achieve learning objectives (Djalal, 2017). In line with Djalal, Affandi (2011) identified learning models as systematic procedures or patterns used as guidelines for achieving learning objectives in which there are strategies, techniques, methods, materials, media, and learning assessment tools. In addition, Nordyke (2011) stated that learning models are systematic pedagogical practices that improve student learning and are designed to plan teaching and curriculum development. Furthermore, Nurdyansyah and Fahyuni (2016) pointed out that a learning model is a plan or pattern that can be used to form a curriculum (long-term learning plan), design learning materials, and guide learning in other classes.

Learning models are procedures designed with simple to complex strategies to help students acquire information, ideas, skills, values, thinking and express themselves (Joyce & Weil, 2009). The attributes of learning models are a coherent theoretical framework, an orientation towards what students should learn, and specific teaching procedures and structures (Arends, 2012). Learning models are designed based on learning theory (Allphin, 2011). Learning models are characterized by (1) Designed based on educational theory and learning theory from certain experts, (2) has a specific educational mission or purpose, (3) can be used as a guide for improving teaching and learning activities in the classroom, (4) has a sequence of learning steps (syntax), (5) has an impact as a result of the application of the learning model, and (6) makes teaching preparation (instructional design) with the guidelines of the selected learning model (Nurdyansyah & Fahyuni, 2016).

Based on the definitions that have been described, it can be concluded that learning models are learning procedures designed with systematic strategies based on learning theory. Educators design the learning model as a guide for learning in the classroom and can also be used to form or develop a learning curriculum. The learning model is a learning procedure from start to finish, so the learning model is a wrapper or frame for applying a learning approach and strategy (Djalal, 2017). Learning models describe an overall approach or plan for teaching (Arends, 2012).

An approach is defined as a way of beginning something (Subanji, 2013: 4). In this case, the approach can be interpreted as a way to start learning. In a broader sense, approach refers to a set of assumptions about how to learn. An approach is a starting point in looking at something, a philosophy or belief that is not always easy to prove. So, the approach is axiomatic, which means that the truth of the theories used is undisputed.

The learning approach is the foundation for starting and carrying out learning in a field of study/subject and gives direction and style to the learning. Approaches are often interpreted as similar to strategies, where the approach is our starting point or point of view towards the learning process. The benefit of the learning approach is that it serves as a general guideline for the learning steps that will be used.

Thus, the learning approach refers to a set of assumptions about how to learn and is a starting point in looking at learning. The learning approach is more directed to the philosophical foundation of learning.

According to Musfiqon and Nurdyansyah (2015), approach is a basic concept that accommodates, inspires, strengthens, and underlies thoughts about how learning methods are applied based on specific theories. Therefore, many views stated that approach is the same as method, even though both are different. Several methods can in one single approach. For example, in undertaking scientific approach, observation, discussion, expository, and other methods can be applied.

There are various classifications of learning approaches. According to Killen (in Sanjaya, 2009), learning approaches can be classified into teacher-centered and student-centered approaches. Approaches in learning mathematics include the constructivist approach, contextual approach, realistic mathematics approach, open-ended approach, and problem-solving approach (Sutarto & Syarifuddin, 2013: 57). In learning mathematics, in addition to those mentioned, other approaches can also be used such as the inductive-deductive approach, spiral approach, and scientific approach.

According to the Big Indonesian Dictionary (*KBBI*) (2019), a strategy is a careful plan of activities to achieve specific goals. At the same time, the definition of learning is more about efforts to teach the learner, so the learning process is the linking of new knowledge to the cognitive structure the learner already has. These links will form a new and more stable cognitive structure, which can be seen as a learning outcome (Degeng, 2013). Therefore, a learning strategy is a careful or systematic plan for teaching students so that they can form new, more stable cognitive structures.

Likened to a soccer game, of course it is not only the quality of each player that determines the outcome of a match. A strategy is always designed individually as well as a team or group in a soccer match. The goal is clearly to win the match. Strategy is needed to develop the ability to think, improvise, and creativity of soccer players, and players can determine the best alternatives in solving problems in every match (Olahragapedia.com, 2020).

According to Shadiq (2009), learning strategies are chosen to deliver subject matter in a particular teaching environment, including the scope and sequence of activities that can provide learning experiences to students. This opinion is based on the constructivist view that learning strategies emphasize content presentation on meaningful use following the sequence from the whole to the parts. Therefore, learning is more directed to serve the questions or views of the learner, with learning activities based more on primary data and manipulative materials emphasizing critical thinking skills, such as analysing, comparing, generalizing, predicting, and hypothesizing. That is why constructivist learning emphasizes the process.

Within each learning model, several strategies can be used. Strategies determine the approach that teachers can take to achieve learning objectives. Strategies can be classified into 5, namely: 1) direct instruction, 2) indirect instruction, 3) experiential learning, 4) independent study, and 5) interactive learning.

Learning strategies are patterns of action that teachers/lecturers use in various teaching events to achieve instructional goals (Djalal, 2017). Learning strategies are steps that students take to improve their learning (Shi, 2017). Strategy can be interpreted as a general pattern of teacher and student activities in realizing teaching and learning activities to achieve the goals outlined (Aji & Budiyono, 2018). Learning strategies are orientations that teachers give to students to improve learning (Enríquez et al., 2018). From several definitions that have been described, learning strategies are stages or learning procedures. Learning stages or procedures are found in the syntax of the learning model.

Implementing a learning strategy involves five steps (TLL, 2002). First, variables: analyzing the key components of learning, including examining students' backgrounds, abilities, prior knowledge, determining learning objectives, and identifying pedagogical strengths. Second, constraints: identifying resource limitations that may impact the teacher's ability to optimally organize and conduct learning. Third, decisions: making critical decisions about how learning will be organized. Fourth, assessment: collect feedback on student learning and the strengths and weaknesses of the learning. Last, refinements: use feedback to improve learning.

The components described above were developed to form an integrated innovative learning design based on TPACK (Technological, Pedagogical, and Content Knowledge) in the Linear Algebra course. The learning design is said to be innovative because it contains a student-centered learning process and is oriented towards Higher Order Thinking Skills (HOTS). Meanwhile, it is said to be integrated because this design combines components in the learning structure, such as strategies, models, approaches, methods, and learning techniques. The TPACK is used as a reference or base for its development so that the developed learning design also contains and combines elements of technology, pedagogy, and material content.

Problem of Research

Based on the description above, the formulation of the problem in this study is as follows:
The students have difficulty solving conceptual problems even though they are not complex problems like the proving simple theorems in linear algebra courses. In addition, based on the results of previous research, it is known that students also have difficulty making connections between concepts and have linear algebra problem-solving skills that tend to be low. Therefore, it is an indication of a problem that needs to be solved through this research so that it can improve students' thinking skills in problem-solving in linear algebra courses.

Method

Research Method

This type of research is exploratory, descriptive research. The approach used is a qualitative approach since it is in accordance with the characteristics of research. Creswell (2012) stated that research is carried out in the field in a natural environment, not in a situation that is conditioned in advance. Researchers meet face-to-face with respondents/subjects of research in collecting research data.

Participants

The research was conducted at the Faculty of Teacher Training and Education University of Mataram, Indonesia. The research subjects were the Department of Mathematics Education students who took Linear Algebra course. Linear Algebra was chosen because it is a staple course in the mathematics education study program. Linear algebra is one of the primary materials in the National Olympiad of Mathematics and Natural Sciences (ON-MIPA) Higher Education in Mathematics. This Linear Algebra course in the Department of Mathematics Education at University of Mataram is offered in semester III.

The study involved 58 students spread across two classes, namely class D, with as many as 31 students and class E, with 27 students. Regarding gender distribution, the class consisted of 10 male and 48 female students. Students in the Faculty of Teacher Training and Education of the University of Mataram, including in the Mathematics Education study program, are dominated by women compared to men.

Data Collection

The data collection techniques used was linear algebra problem-solving test which can be seen as follows.

Tes Pemecahan Masalah Aljabar Linier

Alokasi Waktu: 90 menit

Petunjuk :

1. Naskah terdiri dari 5 butir soal uraian, dengan bobot skor yang sama.
2. Kerjakan soal tanpa membuka buku (close book), dengan alokasi waktu 90 menit.
3. Selamat mengerjakan, semoga sukses.

<u>Soal:</u>

1. a. Jelaskan cara menyelesaikan SPL dengan Metode Eliminasi Gauss Jourdan.
   b. Gunakan Metode Eliminasi Gauss Jourdan (Cara OBE) untuk menentukan himpunan pnyelesaian dari SPL berikut
   $$\begin{cases} x + 2y - 3z = -2 \\ 3x - y + 5z = 1 \\ 4x + y + 2z = -1 \end{cases}$$
2. a. Jelaskan cara menghitung determinan matriks dengan cara ekspansi kofaktor sepanjang suatu baris/kolom.
   b. Gunakan cara ekspansi kofaktor untuk menghitung determinan matriks
   $$M = \begin{pmatrix} 1 & 0 & 1 & 1 \\ 2 & 1 & 3 & 1 \\ 0 & 2 & 1 & 0 \\ 0 & 1 & 1 & 3 \end{pmatrix}$$
3. a. Jelaskan cara menghitung determinan matriks dengan Cara OBE.
   b. Gunakan Cara OBE untuk menghitung determinan matriks
   $$M = \begin{pmatrix} 1 & 0 & 1 & 1 \\ 2 & 1 & 3 & 1 \\ 0 & 2 & 1 & 0 \\ 0 & 1 & 1 & 3 \end{pmatrix}$$
4. a. Jelaskan cara menghitung invers matriks dengan Cara Adjoint.
   b. Gunakan Cara Adjoint untuk menghitung A^{-1} dari matriks $A = \begin{pmatrix} 0 & -2 & 2 \\ 1 & 2 & 1 \\ 1 & 0 & -3 \end{pmatrix}$
5. a. Jelaskan cara menghitung invers matriks dengan Cara OBE.
   b. Gunakan Cara OBE untuk menghitung A^{-1} dari matriks $A = \begin{pmatrix} 0 & -2 & 2 \\ 1 & 2 & 1 \\ 1 & 0 & -3 \end{pmatrix}$.

Figure 1. Algebra problem solving test instrument

The data obtained in this study were analyzed quantitatively using descriptive statistics and qualitatively by describing and providing an overview of the effectiveness of implementing the developed learning design.

Result and Discussion

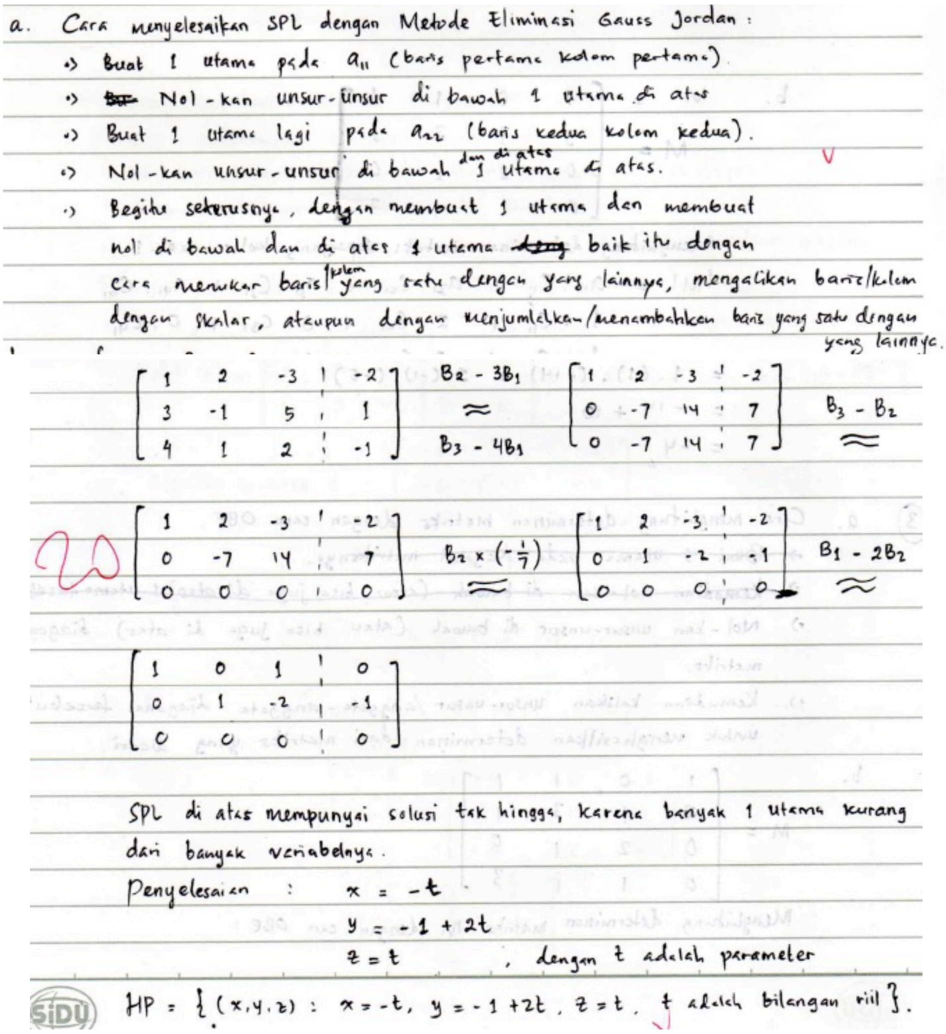
After the research subjects were given linear algebra problem-solving tasks, problem-solving score data were obtained, as in Table 1 below.

Table 1. Problem-solving score data

No.	NIM	Score	No.	NIM	Score
1	E1R020096	60	31	E1R021128	48
2	E1R021097	36	32	E1R021129	59
3	E1R021098	48	33	E1R021130	66
4	E1R021099	30	34	E1R021131	63
5	E1R021100	32	35	E1R021132	13
6	E1R021101	56	36	E1R021134	14
7	E1R021102	96	37	E1R021135	85
8	E1R021103	81	38	E1R021136	16
9	E1R021104	45	39	E1R021137	44
10	E1R021105	36	40	E1R021138	4
11	E1R021106	74	41	E1R021139	60
12	E1R021107	80	42	E1R021140	71
13	E1R021108	24	43	E1R021141	10
14	E1R021109	50	44	E1R021142	47
15	E1R021110	58	45	E1R021143	20
16	E1R021111	78	46	E1R021144	69
17	E1R021112	100	47	E1R021145	85
18	E1R021113	51	48	E1R021146	89
19	E1R021114	34	49	E1R021147	44
20	E1R021115	52	50	E1R021152	63
21	E1R021118	90	51	E1R021153	32
22	E1R021119	67	52	E1R021154	29
23	E1R021120	21	53	E1R021155	32
24	E1R021121	28	54	E1R021156	77
25	E1R021122	71	55	E1R021157	24
26	E1R021123	46	56	E1R021158	55
27	E1R021124	95	57	E1R021159	30
28	E1R021125	28	58	E1R016057	90
29	E1R021126	32			
30	E1R021127	24			

The data classified the research subjects into five categories according to the score range: Very Good, Good, Fair, Poor, and Very Poor. The percentage obtained for these categories is the category of Very Good (17.2%), Good (13.8%), Fair (12.1%), Poor (13.8%), and Very Poor (43.1 Based on the percentages, 43.1% indicates a Fair category, which means more than 50% fall under poor and very poor category. Based on this data, students of the Department of Mathematics Education at Faculty of Teacher Training and Education, University of Mataram, have not effectively applied the TPACK-based innovative learning design developed.

The characteristics of each category were descriptively explored; subjects in the Very Good category were able to explain and implement the ways/steps to solve problems appropriately. In addition, when the problems must be solved with two methods, both can be solved correctly. An excerpt of the answer for subject S-17, which is categorized as very good, is presented in Figure 2 below.


a. Cara menyelesaikan SPL dengan Metode Eliminasi Gauss Jordan :
- Buat 1 utama pada a_{11} (baris pertama kolom pertama).
- Nol-kan unsur-unsur di bawah 1 utama di atas
- Buat 1 utama lagi pada a_{22} (baris kedua kolom kedua).
- Nol-kan unsur-unsur di bawah dan di atas 1 utama di atas.
- Begitu seterusnya, dengan membuat 1 utama dan membuat nol di bawah dan di atas 1 utama baik itu dengan cara menukar baris/kolom yang satu dengan yang lainnya, mengalikan baris/kolom dengan skalar, ataupun dengan menjumlahkan/menambahkan baris yang satu dengan yang lainnya.

$$\left[\begin{array}{ccc|c} 1 & 2 & -3 & -2 \\ 3 & -1 & 5 & 1 \\ 4 & 1 & 2 & -1 \end{array}\right] \underset{B_3 - 4B_1}{\overset{B_2 - 3B_1}{\approx}} \left[\begin{array}{ccc|c} 1 & 2 & -3 & -2 \\ 0 & -7 & 14 & 7 \\ 0 & -7 & 14 & 7 \end{array}\right] \overset{B_3 - B_2}{\approx}$$

$$\left[\begin{array}{ccc|c} 1 & 2 & -3 & -2 \\ 0 & -7 & 14 & 7 \\ 0 & 0 & 0 & 0 \end{array}\right] \overset{B_2 \times (-\frac{1}{7})}{\approx} \left[\begin{array}{ccc|c} 1 & 2 & -3 & -2 \\ 0 & 1 & -2 & -1 \\ 0 & 0 & 0 & 0 \end{array}\right] \overset{B_1 - 2B_2}{\approx}$$

$$\left[\begin{array}{ccc|c} 1 & 0 & 1 & 0 \\ 0 & 1 & -2 & -1 \\ 0 & 0 & 0 & 0 \end{array}\right]$$

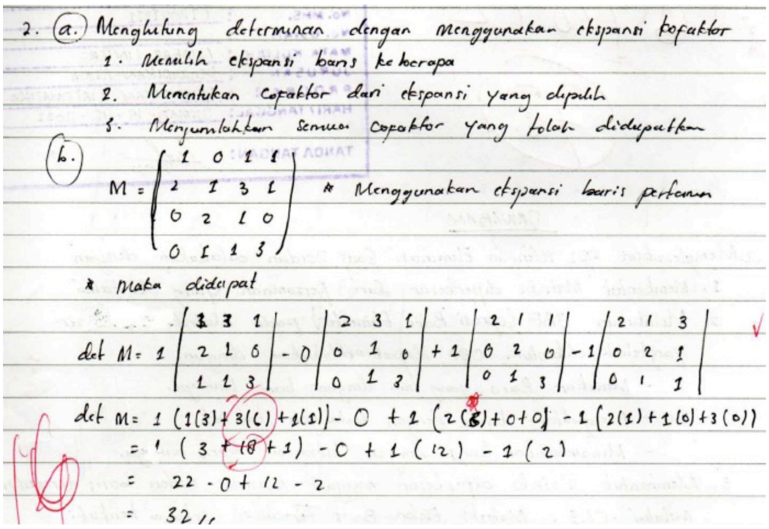
SPL di atas mempunyai solusi tak hingga, karena banyak 1 utama kurang dari banyak variabelnya.

Penyelesaian : $x = -t$, $y = -1 + 2t$, $z = t$, dengan t adalah parameter

HP = { (x, y, z) : x = -t, y = -1 + 2t, z = t, t adalah bilangan riil }.

Figure 2. Excerpt of S-17's answer

The Good category subject was able to explain the method/steps to solve the problem well and was able to implement it in solving the problem case, but there were still shortcomings. Likewise, problems that two methods must solve can only be solved correctly using one of them. Figure 3 below presents an excerpt of subject S-16's answer, categorized as Good.


2. (a.) Menghitung determinan dengan menggunakan ekspansi kofaktor
1. Memilih ekspansi baris ke berapa
2. Menentukan cofaktor dari ekspansi yang dipilih
3. Menjumlahkan semua cofaktor yang telah didapatkan

(b.)
$$M = \begin{pmatrix} 1 & 0 & 1 & 1 \\ 2 & 1 & 3 & 1 \\ 0 & 2 & 1 & 0 \\ 0 & 1 & 1 & 3 \end{pmatrix}$$ * Menggunakan ekspansi baris pertama

* Maka didapat

$$\det M = 1\begin{vmatrix} 1 & 3 & 1 \\ 2 & 1 & 0 \\ 1 & 1 & 3 \end{vmatrix} - 0\begin{vmatrix} 2 & 3 & 1 \\ 0 & 1 & 0 \\ 0 & 1 & 3 \end{vmatrix} + 1\begin{vmatrix} 2 & 1 & 1 \\ 0 & 2 & 0 \\ 0 & 1 & 3 \end{vmatrix} - 1\begin{vmatrix} 2 & 1 & 3 \\ 0 & 2 & 1 \\ 0 & 1 & 1 \end{vmatrix}$$

det M = 1 (1(3) + 3(6) + 1(1)) - 0 + 1 (2(6) + 0 + 0) - 1 (2(1) + 1(0) + 3(0))
= 1 (3 + 18 + 1) - 0 + 1 (12) - 1 (2)
= 22 - 0 + 12 - 2
= 32

Figure 3. Excerpt of S-16's answer

Subjects in the Fair category could explain the ways/steps to solve the problem but were incomplete, and the solution implementation to the problem case was also less than perfect. An excerpt of the answer for subject S-40, which is categorized as Fair, is presented in Figure 4 below.

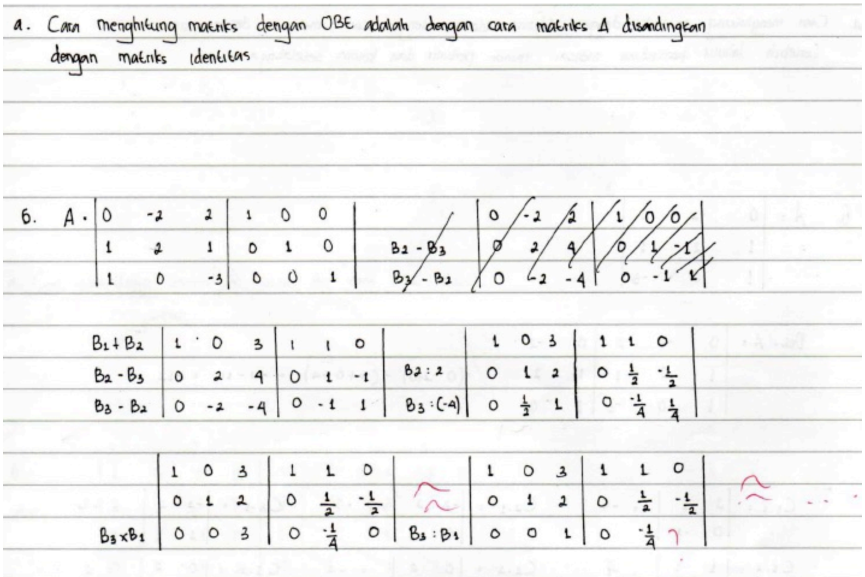


Figure 4. Excerpt of S-40's answer

Subjects in the Poor category was not able to explain the ways/steps to solve the problem well and implement it in solving the problem case, but they have also not been precise. Figure 5 below presents an excerpt of the answer to subject S-18, categorized as Poor.

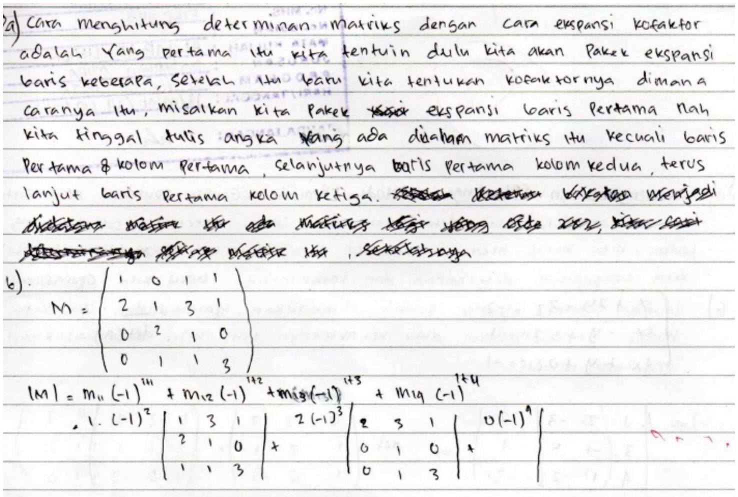


Figure 5. Excerpt of answer S-18

Subjects in the very poor category could not explain the ways/steps to solve the problem, and implementing it in solving the case also did not hit substantially. The excerpt of the answer of subject S-18 who is categorized as Very Poor is presented in Figure 6 below.

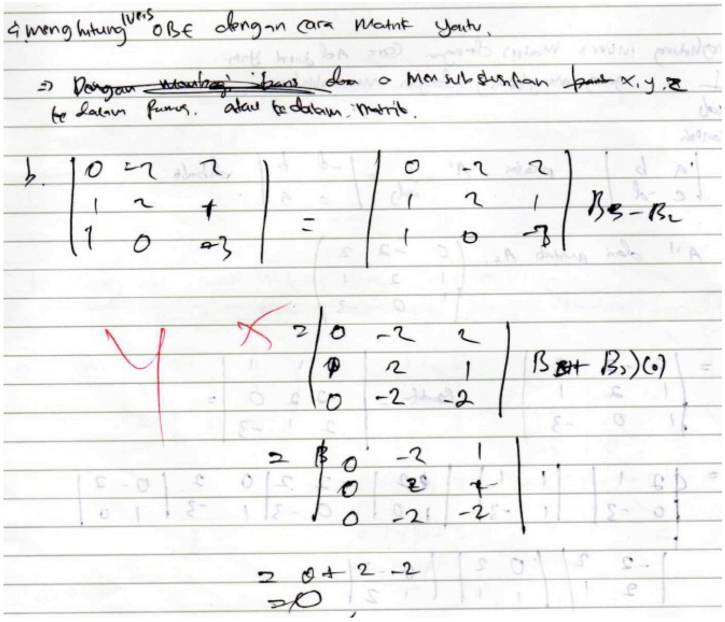


Figure 6. Excerpt of S-05's answer

From Figure 6 above, it can be argued that S-05's explanation in part shows that S-05 did not understand how to determine the inverse matrix with Elementary Row Operations or OBE, so the implementation in part b is also completely wrong.

Furthermore, the discussion was presented in terms of the understanding framework. There are four levels of understanding of mathematical rules, namely: (a) mechanical, i.e., applying memorized methods only; (b) inductive, i.e., exploration of simple cases progressing to complex cases; (c) rational, i.e., proving the rule with something else, (d) intuitive, i.e., self-belief in the truth without doubt (Meel, 2003). Meanwhile, Lehman (1977) equates understanding with three knowledge types: applications, meanings, and logical relationships.

Subjects at the Very Poor category could be classified at the level of mechanical understanding because they apply only the methods they remember, and the results are also less accurate. For example, the participants were asked to use the Gauss-Jourdan elimination method in solving System of linear equations (SPL). However, only the elimination and substitution methods were applied, which made it challenging to handle SPL with infinite solutions, so the results were wrong.

Furthermore, for subjects at a Poor category, the level of understanding can be classified as mechanical and inductive. A memorized method has been done correctly but has not been able to explore other methods or cases. For example, the participants can calculate the inverse by adjoint but cannot develop another method, namely the OBE method.

Subjects at the Fair category have between the inductive and rational level of understanding. They were able to try to solve problems with other rules/ways even though neither of them could get the right results. In this case, for example, calculating the determinant correctly using OBE and being able to develop another way with cofactor expansion, but the results are not yet correct.

Whereas subjects are at Good category, their level of understanding is between the rational and intuitive levels, since they could solve problems with other rules but not yet fully confident in identifying the correct answer. For example, the matrix inverse problem can be solved by the adjoint or the OBE method, but it is still not perfect due to calculation errors/accuracy.

Subjects who are in the Very Good category; their level of understanding is at the intuitive level, which means they can solve problems with complete confidence in the truth without doubt. This can be seen from all the explanations of methods/steps and implementation in various cases of problem-solving ranging from SPL with infinite solutions, calculating determinants with cofactor expansion and OBE methods, to determining the inverse matrix, which can be solved correctly with the OBE method and the adjoint matrix method.

Conclusion

From the research results, it can be concluded that the TPACK-based innovative learning design developed has not been effectively applied to Department of Mathematics Education students as more than 50% are still under the Fair category. For subjects in the Very Poor category, their understanding is still mechanical, meaning they could only apply the memorized method, and the results are less precise. Subjects in the Poor category can use memorized methods correctly but have not been able to develop other methods or cases. Subjects in the Fair category can try to solve problems with other rules/methods even though neither of the results was correct. Subjects in the Good category can solve problems with other rules but did not have confidence in the truth. Meanwhile, subjects in the Very Good category could solve the problems with complete confidence in the truth without doubt.

Recommendations

The things that can be suggested:

- For course lecturers, its hope that they can expand the development of integrated innovative learning designs based on TPACK in other courses in higher education
- For teachers in schools, it is hoped that they can also develop TPACK-based innovative learning designs for mathematics learning in schools.

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