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PRE-SERVICE TEACHERS' PERCEPTION OF THE USE OF GEOGEBRA IN TEACHING AND LEARNING GEOMETRY IN THE COLLEGES OF EDUCATION, GHANA: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

The introduction of technology has given opportunities and made it easy for educators to utilize it in various ways, including in the field of education, as an instrument to support the teaching and learning of mathematics. GeoGebra is one of the mathematical software that can be effectively used in delivering mathematics lessons. GeoGebra is computer software that supports the teaching and learning of mathematics subjects, especially algebra, calculus, geometry, probability, and statistics. The objectives of this systematic analysis were to investigate pre-service teachers' perceptions and benefits of using GeoGebra to teach geometry. This study used a quantitative research design to review published articles from 2011 to 2021 related to the research objectives. This investigation purposefully sampled 17 published articles out of the over 200 articles found. The study used Google scholar, Google, and Sci Direct as the search engines to gather data using the keywords. The selected articles were validated using content analysis. This investigation selected the 17 articles for data analysis based on the research design, location, area of research, research focus and the type of technology applied. The findings of this study disclosed that pre-service teachers had the following perceptions regarding learning geometry with GeoGebra: GeoGebra enhances the teaching and learning of geometry, it helps learners to have positive perceptions concerning GeoGebra integration, GeoGebra improves learners' interest, motivation, and willingness to learn geometry. Also, it motivates learners to interact among themselves. Nevertheless, some benefits were identified as follows: GeoGebra increases students' academic performance, develops learners' confidence in learning geometry, makes the learning of mathematics enjoyable, and helps learners to conceptualize abstract concepts in mathematics. Based on the findings of this study, it is concluded that GeoGebra is effective for teaching and learning geometry. This study recommends that mathematics educators should embrace GeoGebra software in the teaching and learning of geometry at the college level of education. Additionally, the Ministry of Education should enforce the integration of GeoGebra in the delivery of mathematics lessons.

Keywords: mathematics, geometry, GeoGebra, perception, pre-service mathematics teachers

INTRODUCTION

Teaching and learning using technology have many merits including arousing learners' interest in learning mathematics, promoting lifelong learning, and enhancing pre-service mathematics teachers' participation, motivation, and performance. According to Zakaria and Khalid (2016), using technology to teach mathematics facilitates positive interaction and relationships among learners. However, research indicates that some college mathematics facilitators in Ghana do not integrate technology into their instructional process because of time constrain (Agyei & Voogt, 2011). The consequence of this is that pre-service mathematics teachers cannot integrate GeoGebra into the teaching and learning of mathematics. The use of GeoGebra in teaching and learning geometry can help learners to imagine, visualize and understand geometry concepts (Shadaan & Eu, 2013). Several technology tools are available such as Derive 5, Derive 6, Maple, MatLab, Geometer's sketchpad, calculator, and GeoGebra. Since all these technology tools cannot be considered at the same time, this paper focused on pre-service teachers' perception of utilizing GeoGebra in teaching and learning geometry at the College level of Education in Ghana. Further, we looked at the benefits of using GeoGebra to teach and learn geometry.

Furthermore, this section discussed the meaning of GeoGebra, geometry, perception, and pre-service teachers. Although many students believe that geometry is difficult and should not be included in the school curriculum, the use of GeoGebra can curb this allegation (Bowie, Venkat, & Askew, 2019). This software combines features of Geometers Sketchpad, Maple, and Derive (Saha, Ayub, & Tarmizi, 2010) as cited in (Shadaan & Eu, 2013). According to Hohenwarter and Lavicza (2009), GeoGebra is an open-source and user-friendly mathematics software that links algebra and geometry. GeoGebra is a transformative tool because it allows students to interact, manipulate and visualize. Majerek (2014) as cited in Chalaune and Subedi (2020) explained that GeoGebra is an action tool that can be used in teaching and learning algebra, calculus, geometry, probability, and statistics. GeoGebra can be obtained from the website https://www.geogebra.org/download. The researchers could not cover all these strands of mathematics because of the limited time. This study gravitated towards using GeoGebra to teach and learn geometry.

According to Tabak (2004), as cited in Naidoo and Kapofu (2020), geometry is the study of angles, dimensions, shapes, positions, and sizes of objects. Furthermore, Sunzuma, Masocha, and Zezekwa (2013) explained geometry as a field of mathematics that develops learners' spatial awareness, visualization, and enhances students' problem-solving skills. Also, Pesen (2006) as cited in Kakraba (2020) states that geometry is an area

of mathematics that develops students' deductive, critical, and logical reasoning skills. To conclude, geometry is a branch of mathematics that studies the properties of space that are related to the distance, shape, size, and relative position of figures.

Geometry is an integral part of our lives (Markovits & Patkin, 2020). According to Markovits and Patkin, we are surrounded by solids and shapes and interact with them every day. Children are used to solids and shapes. They play with these solids as children and use them for different games. Acquaintance with solids and shapes is very vital because they help young children to develop spatial orientation. Also, children establish the foundations for logical thinking when they play with solids and shapes while investigating the relationships between them. Despite the importance of geometry in our lives and schools, students develop a dislike for school geometry (Zutaah, Miheso-O'Connor, & Ondigi, 2022). To intervene in this situation, the present study investigated if the use of GeoGebra in teaching and learning geometry could boost pre-service teachers' perception concerning integrating GeoGebra into the teaching and learning of geometry.

From an academic perspective, perception concerns the way one sees the world (Mcdonald, 2011). Teachers usually use mathematics software that attempts to uncover and reframe learners' perceptions concerning geometry. This study focused on the use of GeoGebra to uncover and reframe pre-service teachers' perceptions concerning geometry. According to Perreault and McCarthy (2005), as cited in Amodu (2007), perception is the process by which we gather and interpret information from our surroundings. Perception is a process rather than an action because we constantly gather and interpret information from our surroundings. The perception of pre-service teachers about teaching and learning geometry is important in a teacher's ability to help young children develop an understanding of geometric concepts.

Finally, in this study, pre-service teachers refer to students enrolled in Ghanaian colleges of education who are undergoing training to become professional teachers. Training typically lasts four years. The terms pre-service teachers, college students, future teachers, and student teachers are used interchangeably in this study. Nonetheless, studies have been conducted in Malaysia and South Africa on secondary school students' perceptions of teaching and learning geometry using GeoGebra (Shadaan & Eu, 2013; Bayaga, Mthethwa, Bossé, & Williams, 2019). The current study's new focus was on Ghanaian college students. As a result, the goal of this study was to look into future teachers' perceptions of teaching and learning geometry in Ghana using GeoGebra. This study also looked at the advantages of using GeoGebra in teaching and learning geometry.

LITERATURE REVIEW

This section discussed the literature reviewed regarding the research objectives. The literature was reviewed based on the following research objectives: pre-service teachers' perceptions of integrating GeoGebra software into the teaching and learning of geometry, and the benefits of integrating the software into the instruction of geometry concepts. We would start with reviewing the literature on future teachers' perceptions of integrating the software in teaching and learning geometry because that is our first objective. Next, the review would be on the benefits of its integration in the delivery of geometry lessons.

Future Teachers' Perceptions of Integrating GeoGebra in Teaching and Learning Geometry

There are many mathematics software such as geometers sketchpad, maple, and GeoGebra available for teaching and learning geometry in particular and mathematics generally at all levels of education. The software act as a teaching and learning resource for both teachers and learners. Mathematical software helps to motivate learners to study geometry. Many students dislike geometry because they claim geometry concepts are abstract and difficult to understand. Importantly, Ubi and Odiong (2018) established that geometry is hard and disliked by many students. As Ubi and Odiong have convincingly shown in their research, students perceive geometry as difficult because of limited timing, irregular class practices, unavailability, and inappropriate use of teaching and learning materials. To fill up this gap, this study focused on using GeoGebra out of the lot to investigate pre-service teachers' perceptions concerning geometry because GeoGebra is available and free to download from the website.

Globally, Shadaan and Eu (2013) investigated if the use of GeoGebra could help secondary school students solve problems in circles. The study employed a quasi-experimental design. It was disclosed that there existed a significant difference in the mean scores between students in the experimental and control groups in favor of the experimental group. The result clearly shows that GeoGebra has improved secondary school students' performance in circles. Based on this finding, it is important to state that GeoGebra is effective in teaching and learning mathematics. We vehemently agree with the findings of Shadaan and Eu (2013) because the constructivist theory used in the study promoted interaction among students and concept visualization. However, this investigation focused on college students who are receiving training to become professional teachers in Ghana though Shadaan and Eu's (2013) study was on secondary school students in Selangor.

Furthermore, Segal, Oxman, and Stupel (2021) investigated pre-service mathematics teachers' pedagogical and technological knowledge in transformation. The study included twenty-seven future teachers studying to become professional teachers. The students were assigned to experimental and control groups. Students in the control group learned transformation using conventional methods such as using paper and pencil. Nevertheless, participants in the experimental group studied transformation using GeoGebra. The results revealed that the majority (more than 80%) of future teachers indicated that GeoGebra is a good instructional software for revising and expanding students' knowledge in transformation. This indicates that the GeoGebra software had a positive influence on students' achievement and perception of learning transformation. The researchers acknowledge the findings because GeoGebra might promote pre-service mathematics teachers' visualization of concepts. The present study assessed college students' perceptions toward integrating GeoGebra into the instruction of geometry lessons.

Moreso, Dağ, Şumuer, and Durdu (2019) assessed pre-service mathematics teachers' perceptions of geometry concepts using GeoGebra in Turkey. Eighty pre-service teachers participated in the study. The study established that participants demonstrated positive perceptions toward GeoGebra integration. This outcome established that the software allowed learners to visualize geometric concepts and interact among themselves. GeoGebra has positively changed PMTs' perceptions of using the software to teach geometry concepts. As Dağ et al. (2019) show in their research, GeoGebra has positively influenced students' perceptions and experiences regarding teaching and learning using the software. The present study supports the findings of Dağ et al. (2019) because GeoGebra might play a role in motivating learners to share knowledge of geometric concepts. Although Dağ et al. (2019) study was in Turkey, the present study was in Ghana.

In Africa, Mulder (2017) investigated pre-service mathematics teachers' perceptions concerning integrating technology in the delivery of mathematics lessons. Seven future teachers were used for the investigation. The findings indicated that pre-service teachers feel the confidence to utilize technology in the instructional process. The participants pointed out that there was pressure on them when integrating technology into teaching. This shows that GeoGebra is a powerful tool that supports both mathematics educators and learners. However, its application needs constant practice to avoid learners' confusion. As Mulder (2017) has convincingly shown in his work, pre-service teachers feel a sense of pressure to be able to teach using technology. This investigation agrees with Mulder's findings because many teachers are not comfortable

teaching using technology. Even though Mulder (2017) used technology in general the present study investigated the GeoGebra application.

Again, Mokotjo and Mokhele-Makgalwa (2021) conducted a study on South African mathematics educators' perceptions of the value of GeoGebra integration in the mathematics classroom. The study included four secondary school teachers. The finding revealed that mathematics teachers are enthusiastic about applying GeoGebra to teach mathematics. Mathematics educators believed that the software was valuable in teaching mathematics. This finding indicates that the software empowered the teachers and learners in the instruction process which made a significant impact on students' achievement in mathematics. Similarly, Horzum and Ünlü (2017) investigated mathematics teachers' perceptions of GeoGebra and its use. The study reported that the majority (more than 85%) of mathematics teachers agreed to use GeoGebra in teaching mathematics. This study strongly agrees with the outcome of Horzum and Ünlü (2017) because the software had a positive influence on mathematics teachers' perception of learning mathematics. The new angle of the present study was in Ghana while Mokotjo and Mokhele-Makgalwa (2021) was conducted in South Africa.

In Ghana, Salifu (2020) investigated college students' perceptions toward integrating GeoGebra in the learning of the circle theorem in the Northern sector of Ghana. The study used eighty-eight college students. The findings indicate that participants who studied the circle theorem with the software showed positive interest in teaching utilizing GeoGebra. This shows that GeoGebra software had a positive impact on students' performance and perception regarding the learning circle theorem. The findings of Salifu are in line with Shadaan and Eu (2013) who investigated the effectiveness of using GeoGebra on secondary school students' ability to solve problems concerning circles. Based on these findings, there is sufficient evidence to conclude that GeoGebra is an enabler that promotes the instruction of geometric concepts for example, and mathematics as large. Although the present investigation is a review article, that of Salifu (2020) is an original research article.

In summary, studies including Shadaan and Eu (2013) have been conducted on secondary school mathematics teachers using GeoGebra. Nevertheless, the extent to which the application of the software is proven to enhance mathematics teaching among high school teachers. Therefore, the first objective of the present study investigated future teachers' perceptions of utilizing GeoGebra in the instruction of geometry among college students.

Benefits of Utilizing GeoGebra in Geometry Instruction

There are many benefits of teaching and learning geometry with GeoGebra. Many researchers have conducted studies in this area. Let us look at the findings of the various researchers as follows:

Globally, Zakaria and Khalid (2016) investigated the importance and challenges of utilizing Information and Communication Technology (ICT) in mathematics lessons. Zakaria and Khalid reviewed twenty articles. As seen by Zakaria and Khalid (2016), it was established that the application of ICT in the instruction of mathematics is beneficial in the following ways: ICT attracts students' interest in learning mathematics, it increases students' motivation and achievement, it promotes lifelong learning, as well as facilitates positive students interaction and relationships. This shows that teaching and learning mathematics utilizing technology promotes active participation and relational learning. In some cases, if proper supervision is not done by the teacher, learners will end up playing with the resource instead of learning. However, GeoGebra decreased the cognitive load during students learning because it makes concepts clearer. The present study focused on pre-service teachers' perceptions of using GeoGebra to be specific in teaching geometry but not ICT as in the case of Zakaria and Khalid (2016).

In addition, Alkhateeb and Al-Duwairi (2019) assessed the influence of utilizing Sketchpad and GeoGebra on high school pre-service teachers' performance in geometry. One hundred and five (105) students were included in the study. The study was conducted in Jordan. Findings indicated that the use of the software enabled learners to solve problems in geometry. Though Alkhateeb and Al-Duwairi found GeoGebra to be more effective than the sketchpad on student learning, the researchers are not surprised because GeoGebra is more interactive as compared to the sketchpad. On the other hand, a sketchpad is more effective in learning sketches. GeoGebra is a powerful action tool that can support the teaching and learning of algebra, geometry, calculus, probability, and statistics. As Hohenwarter and Lavicza (2009) showed in their research, GeoGebra has an algebra view, calculus view, geometry view, probability, and statistics view. Hence, GeoGebra is suitable for teaching in these areas of mathematics. Whereas Alkhateeb and Al-Duwairi (2019) used high school teachers as the study sample, the present study focused on basic school pre-service teachers who will be teaching in basic schools after completion.

Also, Celen (2020) assessed secondary school students' views on integrating GeoGebra software in instructing geometry lessons. The study used fourteen students in Turkey. The study revealed that the software promotes mathematics learning. Again, the finding showed that GeoGebra helps students in concretizing abstract concepts in mathematics. This shows that GeoGebra helps learners to solve problems concerning

geometric concepts which results in students' academic achievement. The implication is that mathematics educators should use GeoGebra in the mathematics classroom. The present study acknowledges the findings of Celen (2020), however, students with low computer literacy can have difficulties in applying GeoGebra activities. Zakaria and Khalid (2016) pointed out that low computer literacy is one of the constraints in learning mathematics using technology. The new angle of the present study is in Ghana but Celen (2020) was in Turkey.

In Africa, Bayaga et al. (2019) assessed the impact of implementing GeoGebra software on students learning of geometry. The investigation was carried out on one hundred and twelve (112) South African senior high school students. The study observed a statistically significant effect on students learning geometry. The analysis of the questionnaire items also reported that students appreciated the use of GeoGebra in learning geometry. These findings show that GeoGebra is capable of enhancing students' academic achievement in geometry. Again, it is important to state that GeoGebra motivates learners in the teaching and learning process. This implies mathematics instructors should employ the software in mathematics classrooms. The use of GeoGebra can encourage interaction among students leading to high academic achievement. However, the study of Bayaga et al. (2019) was conducted on high school students in South Africa while the present investigation focused on future mathematics teachers in the colleges of education in Ghana.

In addition, Wassie and Zergaw (2019) investigated the importance and challenges of using GeoGebra in a mathematics classroom in Ethiopia. Forty (40) articles were reviewed. The findings showed that GeoGebra increases students' interest and achievement in mathematics. This result shows that GeoGebra helped learners to actively participate in the teaching and learning process. The implication is that mathematics educators would be willing and frequently use the software in their mathematics lessons. While the study by Wassie and Zergaw (2019) was carried out in Ethiopia, the focus of the present study was in Ghana. GeoGebra is an action tool that fosters students' interest and achievement in mathematics. Tamam and Dasari (2021) conducted a reviewed literature study and reported that GeoGebra helps learners to solve problems in geometry.

Another study conducted by Mwingirwa and Miheso O'Connor (2016) assessed Kenyan high school mathematics educators' perspectives concerning teaching with GeoGebra. Findings indicated that GeoGebra motivated high school teachers to show a willingness to teach mathematics with GeoGebra. This means that GeoGebra empowered both teachers and learners in the teaching and learning of mathematics. It was disclosed that GeoGebra is a powerful mathematics software that is capable of attracting teachers' interest to employ the software in teaching mathematics. Though Mwingirwa and Miheso

O'Connor (2016) carried out their investigation on senior high school practicing teachers in Kenya, the present study focused on college students in Ghana who are receiving training to become professional teachers. These future teachers will be teaching in basic schools after completion.

In Ghana, Badu-Domfeh (2020) assessed the impact of GeoGebra integration in the instruction of circle theorem among senior high school students. The study included seventy-eight participants in the Bono Region of Ghana. The findings indicated that GeoGebra software enhances students' performance in geometry. Again, the software was found to be boosting students' interest to learn geometry to be specific and mathematics in general. This outcome indicates that the software is an action tool in increasing learners' performance in geometry to be specific and mathematics in general. This implies both mathematics teachers and learners are willing and will frequently use the software in the mathematics classroom. Based on the outcome of Badu-Domfeh (2020), it is important to conclude that GeoGebra is a mathematics tool that can improve students' performance in geometry for example, and mathematics in general. This implies GeoGebra software promotes learners' academic performance and attitude regarding the learning of geometry. The present study focused on college students' perceptions of using GeoGebra to learn geometry in the colleges of education while Badu-Domfeh (2020) was conducted on secondary school students.

To summarize, studies including Badu-Domfeh (2020) have been conducted on senior high school students. Nevertheless, the extent to which the application of the software is proven to improve learners' performance in mathematics. Therefore, the focus of the present study is on college students.

Geometry helps learners to relate concepts in the classroom to the real world. Additionally, it is a fundamental course for learners to learn other branches of mathematics. Furthermore, geometry helps learners to visualize abstract concepts in mathematics. On the other hand, inadequate knowledge of pre-service mathematics teachers in geometry would make them unable to relate concepts in the classroom to the real world. Again, they would not be able to visualize abstract concepts in mathematics. Despite the importance of geometry to learners, college students in Ghana perceive geometry as difficult (Zutaah et al., 2022). Although the teacher delivers the expected knowledge to help students understand geometry concepts, students seem not to like solving tasks concerning geometry. Something more may be needed to guide students to develop an interest in geometry. As Shadaan and Eu (2013) aptly show where pre-service teachers faced challenges in studying geometry and many demonstrated a dislike for geometry as a subject.

GeoGebra can play a role in filling up the gap by helping pre-service teachers to visualize and develop an interest in geometry through exploration. Also, using GeoGebra could have a positive influence on students' perception of geometry. Therefore, this study investigated if the use of GeoGebra could have an impact on pre-service teachers' perception of geometry. Further, the study assessed the benefits of integrating GeoGebra into the teaching and learning of geometry.

RESEARCH QUESTIONS

This paper was guided by the following questions:

a) What are pre-service teachers' perceptions of using GeoGebra to teach and learn geometry?
b) What are the benefits of using GeoGebra to teach and learn geometry?

RESEARCH METHODOLOGY

In this section, we discussed the research methodologies that were used in the study. This study used a quantitative research design to collect and analyze the data. This investigation highlights studies conducted in the field of applying GeoGebra in teaching and learning geometry. This review article was carried out to collect information on future teachers' perceptions concerning integrating GeoGebra in the delivery of mathematics lessons from previous investigations on geometry. This investigation used Google Scholar, Google, and Sci Direct to search the information using the following keywords: pre-service teachers' perceptions of utilizing GeoGebra to deliver geometry lessons; and the benefits of teaching geometry with GeoGebra. The present study used these tools because they are the leading databases that consist of bibliographic documents with full-text articles in various disciplines, especially for educational multidisciplinary research (Aliyu, Osman, Daud, & Kumar, 2021). The literature was chosen in the English Language. Furthermore, this study used scholarly works from 2011 to 2021 related to geometry instruction utilizing GeoGebra software. All articles before 2011 were excluded from the examination. Even though the GeoGebra software was developed in 2001 by Markus Hohenwater, the 2011 to 2021 duration was chosen to enable the researchers to obtain current information concerning the research objectives. This investigation found more than two hundred (200) published articles on integrating technology into teaching and learning mathematics. Notwithstanding, this investigation utilized seventeen (17) studies from Ghana, Africa, and Abroad to analyze the data concerning the research focus: pre-service teachers' perceptions and benefits of teaching geometry with GeoGebra. This study selected 17 out of 200 articles that are scholarly works, have full–text, and are peer-reviewed using the Mendeley library online. Furthermore, this study considered the

scope, the respondents involved, and the context of the study to draw the articles for the study. See Figure 1 below for the summary of the selection process of the 17 published articles for data analysis.

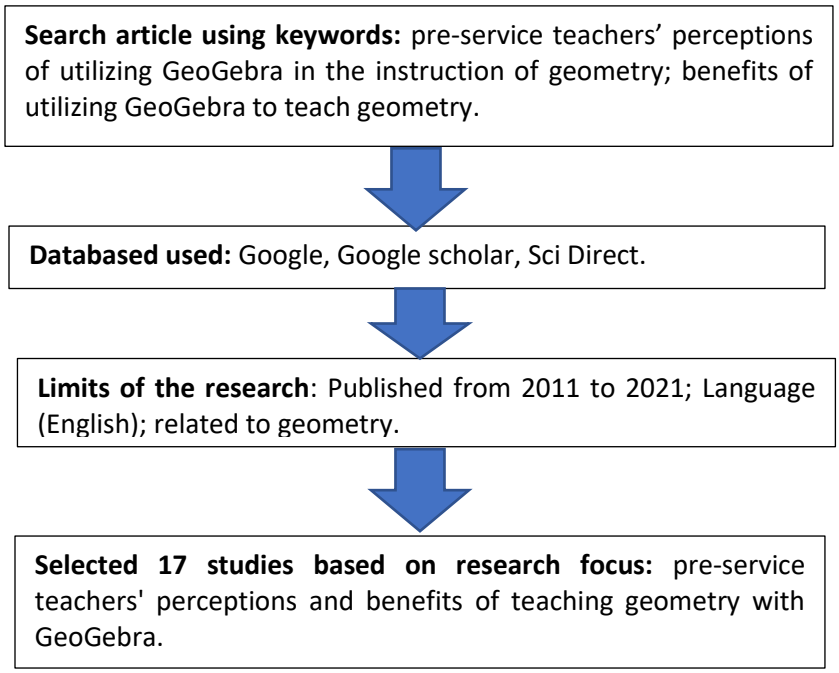

Figure 1. The Selection Procedure of 17 Articles for Data Analysis

Moreso, Table 1 below gives the summary of the 17 selected articles for data analysis. The summary considered the research design, location, research focus, area of research, and the application of the software used. The findings of the selected published articles helped this study to gather data to respond to the research questions. Also, this investigation checked the validity of the selected articles utilizing the content analysis to obtain the required information for the study.

Table 1. Summary of Seventeen Articles Selected for Data Analysis

Research Design	Location	Research focus	Area	Software
Quasi-experimental (9)	Abroad (8)	Educators (4)	Mathematics (8)	Sketchpad (1)
Mixed-method (1)	Africa (6)	Students (13)	Geometry (9)	GeoGebra (15)
Qualitative (5)	Ghana (3)			ICT (1)
Concept paper (2)				

A look at Table 1 above shows that this study used 17 articles in the data analysis of which nine (9) of them used a quasi-experimental design, one (1) mixed method design, five (5) qualitative design, and two (2) concept papers. Again, out of the 17 articles, eight

were conducted Abroad, six were in Africa, and three of them in Ghana. Furthermore, Table 1 indicates that out of the seventeen articles, four of them focused on mathematics educators while thirteen of them focused on students. Also, eight of the seventeen articles were in the area of mathematics in general and the remaining nine were in the area of geometry specifically. Finally, among the seventeen articles, one of the studies used sketchpad software, fifteen of them used GeoGebra software, and the remaining one used ICT.

Finally, to answer the research questions, this study analyzed the data using descriptive statistics from SPSS, such as mean and percentages and reported the results in tables. Garth (2008) states that descriptive statistics are used in SPSS to respond to research objectives, while kappa analyses are used to test the hypothesis. The kappa analysis is used to determine whether two raters agree or disagree. According to Garth (2008), because this study used research objectives, descriptive statistics such as the mean and percentage were used to answer the research questions.

RESULTS AND DISCUSSIONS

Here, we discussed the study findings. This investigation presented the findings according to the research questions. First, the discussion was on future teachers' perceptions of teaching geometry utilizing GeoGebra. Second, this study discussed the findings on the benefits of integrating GeoGebra into the instruction of geometry.

Future Teachers' Perceptions of Integrating GeoGebra in Geometry Instruction

This study assessed future mathematics educators' perceptions of integrating GeoGebra software into the instruction of geometry to answer research objective one (1). Out of the 17 articles reviewed, the outcome of 10 of the articles was a response to research objective 1. Based on the analysis of the 10 articles, the findings are presented in Table 2 below.

Table 2. Pre-service Teachers' Perceptions of Using GeoGebra in Teaching and Learning Geometry

Theme	Number	Percent (%)
GeoGebra enhances the teaching and learning of geometry	3	30
GeoGebra helps learners to have positive perceptions concerning GeoGebra integration	1	10
GeoGebra improves learners' interest, motivation, and willingness to learn geometry	5	50
GeoGebra motivates learners to interact among themselves	1	10
Total	10	100

A look at Table 2 above indicates that pre-service teachers have the following perceptions toward integrating GeoGebra into the instruction of geometry. Three of the studies representing 30% indicate that GeoGebra enhances the teaching and learning of geometry, one (1) representing 10% shows that GeoGebra helps learners to have positive perceptions concerning GeoGebra integration, five articles representing 50% established that GeoGebra improves learners' interest, motivation and willingness to learn geometry. Again, one article representing 10% reported that GeoGebra motivates learners to interact among themselves. This result shows that GeoGebra is powerful computer software that can improve learners' academic achievement in geometry and build their confidence as well as their interest to learn mathematics. This implies mathematics educators and learners are willing and would frequently use the software in the mathematics classroom.

The outcome of this investigation established that the software promotes future mathematics teachers' understanding of mathematical concepts. Again, GeoGebra empowered mathematics instructors and learners in the delivery of mathematics lessons. The study findings are in line with that of Agyei and Benning (2015) who investigated future teachers' perceptions of GeoGebra software as an instructional tool for mathematics lessons. Agyei and Benning (2015) found that GeoGebra increased participants' willingness and frequency to use the software in their future mathematics classrooms. Similarly, Segal et al. (2021) investigated pre-service mathematics facilitators' perceptions of using Geogebra in delivering concepts in transformation and reported that the software is a useful instructional tool for expanding learners' knowledge in transformation. This shows that GeoGebra is effective in the teaching and learning of geometry in particular and mathematics in general. The implication is that mathematics educators and learners should embrace the use of the software as an instructional tool

for mathematics. The use of GeoGebra can encourage active participation among learners to share knowledge and skills. Indirectly, this increases students' performance in geometry in this case and mathematics in general.

Furthermore, the findings of this investigation show that pre-service teachers are willing and would frequently use GeoGebra in their mathematics classrooms. This is supported by the finding of Belgheis and Kamalludeen (2018) who investigated mathematics teachers' intention to use GeoGebra in teaching mathematics in Malaysia. The study of Belgheis and Kamalludeen (2018) used a quasi-experimental design. A workshop was organized for mathematics teachers where some were trained using GeoGebra and others using the traditional method. The study observed a significant difference between participants in the experimental and control groups in their intention to use the software in their mathematics classrooms favoring the participants in the experimental group. Based on the finding of Belgheis and Kamalludeen (2018), there is sufficient evidence to state that GeoGebra is an action tool that boosts mathematics teachers' and learners' interest to use it in the mathematics classroom.

Also, the outcomes of the present investigation are in line with that of Horzum and Ünlü (2017) who assessed future teachers' opinions concerning GeoGebra and its use. It was established that all participants mentioned that GeoGebra has positive effects on their professional development. Again, all participants stated that the software can improve learners' academic performance in geometry. Finally, the findings indicate that all participants concluded that they would like to utilize the software as an instructional tool in the mathematics classroom. This shows that GeoGebra is an effective instructional tool that can empower educators and learners in the instruction of mathematics lessons. This implies that future teachers believed that the software enhances the teaching and learning of geometry concepts.

Moreso, this study's findings support that of (Alkhateeb & Al-Duwairi, 2019; Badu-Domfeh, 2020; Salifu, 2020; Shadaan & Eu, 2013; Wassie & Zergaw, 2019; Zakaria & Khalid, 2016) who reported that pre-service teachers mentioned that GeoGebra improves students academic performance in mathematics. The use of GeoGebra promotes active participation among learners to share knowledge and skills. Indirectly, this increases students' performance in geometry. Similarly, the findings from two studies revealed that GeoGebra promotes a positive perception of using GeoGebra in learning geometry when students were allowed to interact among themselves (Shadaan & Eu, 2013; Dağ et al., 2019). Indirectly, the active participation among learners during the instructional process enhanced knowledge sharing.

Additionally, the findings of this investigation established that GeoGebra has provided a valuable instrument for revising and expanding pre-service teachers'

knowledge in transformation. This finding supports (Segal et al., 2021). This means that GeoGebra is a powerful mathematics action tool that can build confidence in future teachers to integrate technology into the instruction of geometry. This supports the constructivist theory which emphasizes the use of technology, social interaction, and self-exploration to promote an understanding of geometry concepts. Indirectly, future teachers' understanding leads to their confidence to integrate GeoGebra in the teaching and learning of geometry concepts.

Finally, this study's findings established that pre-service mathematics teachers showed positive interest in instructing mathematics using GeoGebra, mathematics educators believed that GeoGebra could promote their enthusiasm, and increase students' motivation. These findings are supported by that of (Mokotjo and Mokhele-Makgalwa, 2021; Salifu, 2020; Zakaria & Khalid, 2016).

Based on the outcomes of this investigation, there is sufficient evidence to conclude that GeoGebra is an effective instructional tool for teaching and learning geometry in particular and mathematics in general. Also, GeoGebra can improve student academic achievement.

Benefits of Integrating GeoGebra in Geometry Lessons

Research has revealed some advantages of integrating GeoGebra software into the teaching and learning of geometry. This study investigated the benefits of integrating GeoGebra into the teaching and learning of geometry to answer research objective 2. The outcome of the analysis of 7 out of the 17 articles responded to research objective 2. The findings from the 7 published articles are summarized in Table 3 below.

Table 3. Importance of Teaching Geometry with GeoGebra

Theme	Number	Percent (%)
GeoGebra increases students' academic performance	3	42.8571
GeoGebra develops learners' confidence in learning geometry	2	28.5714
GeoGebra makes the learning of mathematics enjoyable and fun	1	14.2857
GeoGebra helps learners to conceptualize abstract concepts in mathematics	1	14.2857
Total	7	100

From Table 3 above, 3 (42.8571%) studies indicate that GeoGebra increases students' academic performance, 2 (28.5714%) disclosed that GeoGebra develops

learners' confidence in learning geometry, 1 (14.2857%) show that GeoGebra makes the learning of mathematics enjoyable, and fun. Additionally, 1 (14.2857%) revealed that GeoGebra helps learners to conceptualize abstract concepts in mathematics. This outcome indicates that GeoGebra software is a powerful instructional software that is capable of improving learners' academic achievement. This implies that mathematics instructors and learners would accept GeoGebra integration in the mathematics classroom.

The findings of this investigation are in agreement with that of Alkhateeb and Al-Duwairi (2019) who reported that Sketchpad and GeoGebra helped learners solve geometry concepts. Also, according to the findings of Alkhateeb and Al-Duwairi (2019), GeoGebra had more effect than sketchpad on learners' academic achievement. This shows that both software is good for teaching geometry but GeoGebra seems to be more interactive than a sketchpad. Based on the findings of Alkhateeb and Al-Duwairi (2019), there is enough evidence to state that GeoGebra has more effect in delivering geometry concepts.

Furthermore, these findings concur with the research by Dahal, Shrestha, and Pant (2019) who conducted a study on the impact of GeoGebra and students' performance in transformation concepts. The finding indicates that GeoGebra is useful in improving students' academic achievement in transformation concepts. Based on the finding of Dahal et al. (2019), it makes sense to state that GeoGebra is important educational software that supports mathematics instruction.

Moreso, it was disclosed from the findings of this study that GeoGebra improves students' performance in geometry in this case and mathematics in general. This finding is supported by that of Mukamba and Makamure (2020) who researched integrating GeoGebra into the instruction of geometric transformation and found that GeoGebra improved learners' performance in geometric transformation more than those who learned geometry using the traditional methods. This shows that GeoGebra helped participants who learned geometry using the GeoGebra to understand geometric concepts more than their counterparts who learned the same concepts using the traditional method. According to the outcome of this research, it makes sense to state that GeoGebra is an effective instructional mathematics software for increasing the mastery and retention of mathematics concepts.

Also, the findings of this investigation established that GeoGebra increases students' academic performance in geometry. This outcome concurs with that of Bayaga et al. (2019) who reported that GeoGebra had a statistically significant effect on the students to correctly complete problems concerning some circle geometry. In addition to GeoGebra helping students to complete problems regarding circle geometry, it made

students appreciate it in the mathematics classroom. The GeoGebra software motivated learners to keep solving mathematics questions until the correct answers were obtained. Indirectly, this method might have increased students' motivation and interest to keep trying.

Finally, these findings of the present study support that of (Badu-Domfeh, 2020; Celen, 2020; Chalaune & Subedi, 2020; Wassie & Zergaw, 2019) who have convincingly shown in their research that GeoGebra makes students conceptualize abstract concepts in mathematics. This shows that GeoGebra serves as a scaffold to enhance students' understanding of geometry concepts specifically and mathematics in general. In the GeoGebra environment, students are allowed to explore, visualize, and interact among themselves to share knowledge. From this perspective, the teacher acts as a facilitator. However, it seems reasonable to state that students with low computer literacy might have difficulties in applying GeoGebra activities. Based on the findings of this investigation, there is sufficient evidence to state that GeoGebra is a powerful mathematics software for both teachers and students in teaching and learning mathematics.

Conclusion

This research observed that pre-service teachers had the following perceptions regarding learning geometry using GeoGebra: GeoGebra enhances teaching and learning of circles, encourages positive interaction among students, promotes positive perception regarding the use of GeoGebra, perceived GeoGebra as a valuable instrument, promotes students' enthusiasm, as well as increases students' motivation, interest, and lifelong learning.

However, the use of GeoGebra is important in the following ways: GeoGebra enhances students' performance in geometry, makes the learning of mathematics fun and enjoyable, facilitates students to conceptualize abstract concepts in mathematics, and builds pre-service teachers' confidence to teach and learn geometry to be specific and mathematics in general.

Recommendation

Regarding the outcome of the analysis of the selected studies, the following suggestions were made:

a) Mathematics educators should increase the amount of training for pre-service mathematics teachers regarding GeoGebra integration.
b) It is proposed that the Ministry of Education should enforce GeoGebra integration in the teaching and learning of mathematics in colleges of education in Ghana.

Moreso, this study suggested further studies in the following ways:

a) Further study should be carried out on future mathematics educators' perceptions of utilizing GeoGebra in teaching and learning algebra, calculus, trigonometry, and statistics.
b) Since this research investigated the benefits of using GeoGebra in instructing geometry, it is suggested that a further study should be conducted on the challenges of integrating GeoGebra into geometry lessons at the college level of education.

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Author contributions

All authors have sufficiently contributed to this study and agreed with the results and conclusions.

Declaration of Interest

All the authors declared no conflict of interest.

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INVESTIGATING SOCIAL SCIENCE STUDENTS' UNDERSTANDING OF LIMITS THROUGH THE LENS OF THE PROCEPT THEORY

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ABSTRACT

The study reported in this paper sought to investigate how social science students understand the idea of limit with regard to the use of its symbolism. Sixty first year university students in the social sciences acted as the sample of the study. An adapted procept theory was used to analyse data obtained from these students through their solution to tasks on limit and explanations on their thinking and solution processes. Data analysis indicated that some students understood the limit symbolism $\lim_{x\to a} f(x)$ *to be a procept while others did not. When solving the mathematical tasks, students' difficulties emanated from: (i) their inability to coordinate the two processes,* $f(x) \to L$ *and* $x \to a$*, or* $f(x) \to L$ *and* $x \to \infty$ *(ii) the proper use of the limit operator,* $\lim_{x\to a}$*, and (iii) inability to realise that the simplification has led to the same response as they could not see the relationship between their working and the results. This resulted in misalignment between their reasoning and their choice of answers where justification was required. The results also show that limits at infinity were more problematic than those of the form* $f(x) \to L$ *as* $x \to a$*, where a is a constant. Students' choice of method used depended mostly on how much efficient the method was in terms of saving time and not really on promoting understanding.*

Keywords: procedure, process, concept, procept, limits, mathematical symbols

INTRODUCTION

Research in mathematics and mathematics education has shown that success in mathematics requires much more than being good at carrying out algorithmic or mechanistic procedures that lead to the solution of the mathematics problem at hand (García-García & Dolores-Flores, 2021; Mellor, Clark & Essien, 2018). Such algorithmic processes need to be complemented by some kind of a holistic grasp of the context (Essien, 2021; Tall & Thomas, 1991). In the mathematics context, symbols are important in helping to mediate the cognitive processes around the concept at hand, and also enable performing operations on them (Güçler, 2014). This is because symbols are tools with which to represent concepts (objects) and processes (Gray & Tall, 1994; Güçler, 2014). Through the use of symbols, many students however write procedures which are hardly related to their conceptual meaning in solving mathematical problems (Tall & Thomas, 1991). This sequential (procedural) process of responding to questions poses a lot of problems for a variety of reasons: (i) an incorrect answer may be obtained and failed to be recognised; and (ii) there may be difficulties in answering questions which require interpretation. To address this problem, teachers need to

unpack the meanings inherent in symbols to enhance mathematical communication in the classrooms (Güçler, 2014). Hence, the use and interpretation of symbols are not necessarily without problems, as in some contexts in mathematics, in particular limits for example, the same symbol may represent both the concept and the process (Tall & Thomas, 1991; Güçler, 2014). As an example, the notation $\lim_{x\to a} f(x)$ represents both the process of *tending to a limit* and the concept of the *value of the limit.* This dual nature of mathematical symbols as a process and a concept is referred to by Tall and Thomas (1991) and Gray and Tall (1994) as a *procept*. In other words, this dualism shows the role of symbols in mathematics as tools that allow the human mind to switch effortlessly from "concepts to think about" to "processes to solve problems" (Tall, n.d. p.1). Sfard (1991) refers to this dualism structurally - as objects, and operationally - as processes. According to Sfard (1991):

> Seeing a mathematical entity as an object means being capable of referring to it as if it was a real thing - a static structure, existing somewhere in space and time. It also means being able to recognize the idea "at a glance" and to manipulate it as a whole, without going into details.… In contrast, interpreting a notion as a process implies regarding it as a potential rather than actual entity, which comes into existence upon request in a sequence of actions (p.5).

Another type of limit referred to as *limit at infinity*, denoted by $\lim_{x\to\infty} f(x) = L$ or $\lim_{x\to\infty} f(x)$, may also be viewed as a procept (Gray & Tall, 1992). But as Gray and Tall (1992 cautions, it is important to note that not all mathematical concepts can be viewed as procepts.

The empirical work that has been done to investigate students' understanding of limits were mostly in the fields of natural sciences (Moru, 2009; Maharaj, 2010; Güçler, 2014; Jones, 2015) engineering and mathematics (Güçler, 2014; Jones, 2015), and Technology (Cottrill et al., 1996; Güçler, 2014). We did not come across any studies on limits in the social sciences where students do not take mathematics as their major subject. To address this concern, the purpose of the reported study was to investigate how social science students understand and respond to problems on limits represented algebraically. This is because this is the context in which symbols seem to show their dual nature (Sfard, 1991; Gray and Tall, 1994; Güçler, 2014; Jones 2015). As Güçler (2014) contends, the issue for learners is not whether they consider limits as processes or objects but whether they can consider limits as also depending on the mathematical context. Such a flexible utilisation of the limit notation requires the understanding of the concept of limit together with the processes associated with it (Gray & Tall, 1994).

As the title suggests, the sample of the study is the social science students. These students are required to understand the idea of limit because of its applicability in their area of study. In marginal analysis, social science students engage in ideas such as marginal supply, marginal demand, marginal propensity to save and to consume and many more. The mode of representation of concepts in such contexts make use of symbols and the most prominent symbols are that of the idea of limit. Symbols representing limits may be seen as concepts,

processes or procepts. Understanding these conceptions enable students to interpret the obtained numerical or algebraic results in solving problems within their field with great depth and accuracy. Thus, it is of absolute necessity for students' work or understanding to be analysed using the Procept Theory framework.

The following research questions emanated from the purpose of the study:

1. How do Social Science University students understand mathematical symbols representing the idea of limit?
2. What methods or techniques do they employ in solving mathematical tasks on limits?
3. What justification(s) (if any) do students give for a preferred method in solving tasks over the other?

We believe that the findings of the study will contribute to the literature on how symbols in calculus, especially in limits, are understood by students who are non-mathematics majors. The findings will also show why students prefer certain methods or procedures to others. The questions that are important to us as far as research questions 2 and 3 are concerned are: Is the procedure or method chosen on the basis of its importance in improving understanding? Are the procedures chosen based on its efficiency? Is there a valid reason for a preferred procedure/method?

THE TEACHING AND LEARNING OF LIMITS

The idea of limits was not an explicit construct in its early development but since the 19th century, it has been considered a central concept in calculus (Viirman, Vivier & Monaghan, 2022). In teaching, both the dynamic and the informal language of limits was used. The static language of limits involving the $\varepsilon - \delta$ notation only became prominent after the 19th century (ibid.). Since the current study focuses on the former language, the studies considered in the literature review will exclude the latter.

Monaghan (1991) found that some students had problems with the limit concept because of the ambiguity inherent in the phrases and terms used in its context (also see Viirman et al., 2022). These include phrases and terms such as: 'tends towards', 'approaches', "close to" and 'limit'. The phrase 'tends towards' may mean either approaching and reaching or approaching without reaching (Cornu, 1991). According to Taback (1975), the word reach may mean being in the neighbourhood of a point or landing on a point. Williams' (1991) study revealed that students perceived the idea of limit as a boundary or something unreachable, the meaning that overlaps with that of Cornu (1991). The phrase 'close to' poses problems as to how close one can be to the point that is being approached. This becomes difficult for students especially when choosing numbers in the neighbourhood of the number that is being approached. Is one allowed to be a tenth, a hundredth or a millionth away? Such skills of making proper choices need the proper understanding of the concept of number as each point or number chosen has to be in the direction of the number that is being approached either from the left-hand side or the right-hand side.

The difficulties that students encounter when dealing with solving problems in limits as Moru (2009) concluded from her study include: (i) the limit does not exist where the

function is not defined, (ii) If $f(x)$ is not defined at a point, the functions values tend to infinity, and (iii) that the function value is the limit value. Cottrill et. al. (1996) attribute the main problem of lack of understanding of the limit concept by the students as failure to coordinate the two processes $f(x) \to L$ as $x \to a$. In the same light, Denbel's (2014) study shows that some of the students' misconceptions about the idea limit are that: (i) students think that limits simply entail substituting the value at which the limit is to be found, into the expression, (ii) they often think that limits are only encountered when trying to ascribe a value to a function at a point where was same, (iv) students talk of a limit not being defined at a point, when it is the function that is not defined at the point, and (v) students think only about the manipulative aspects and do not focus on the idea of the limit. With regard to the interpretation of what the limit value is, there is an overlap with the descriptions given by Williams (1991). Some students interpreted the limit as the boundary. This shows how everyday language influences students' understanding of some technical terms in mathematics. Students are not aware that such terms carry a different meaning in the mathematical context as the meaning of words or terms is context bound.

Güçler (2014) conducted a study which addressed the question: "How do one instructor and his students use and think about the limit notation in a beginning-level undergraduate calculus classroom?" (p.251). The findings of the study show that although the instructor differentiated between the process and the product aspects of the limit, students still perceived the limit as a process when using its notation. In the same vein, Jones (2015) conducted a study that sought to investigate the dynamic reasoning used by undergraduate students when thinking about, calculating, and interpreting limits at infinity. The type of infinity considered here is the *potential* and not the *actual* infinity. The potential infinity is taken as a never-ending process while the actual infinity is the existent entity such as the number of elements in the set of integers, for example. In dealing with limits at infinity, in Jones' (2015) study, students are said to have taken ∞ as a quantity that can be substituted for a variable and be manipulated. For example, in finding the limit of $f(x) = \frac{1}{x}$ as x tends to ∞, the symbol ∞ was substituted for x and $\frac{1}{\infty}$ was simplified to zero. Thus, the students did not take into consideration the process of tending to which is the dynamic feel that the potential infinity has. Other students regarded infinity as a big number that could either be negative or positive.

As in the case of Jones (2015), an earlier study by Maharaj (2010), undergraduate science students were asked to find the limit at infinity of rational functions. In addition, students had to find the limit of a rational function not defined at $x = a$. The question on limits at infinity read: the following infinite limit is equal to $\lim_{x\to\infty} \frac{-3x^2+3x-8}{-6x^2+10}$, A) $\frac{-5}{4}$ B) 0 C) ∞ D) $\frac{1}{2}$ E) None of these. Out of 868 students, only 400 (46.1%) chose the correct answer (D). Handling ∞ seems to have been problematic for most students. It was necessary for students to realise that in this case, the procedure is to divide both the numerator and the denominator by the highest power of a variable in the denominator and all the terms whose denominators

have the power of x greater zero should have zero as their limit. This would leave the quotient of -3 and -6 which is $\frac{1}{2}$ that no longer depends on x, hence the limit value. Another question in Jones (2015) on finding the limits of rational functions not defined at $x = a$ read: the following $\lim_{x\to 36} \frac{\sqrt{x}-6}{x-36}$ is equal to: A) $\frac{1}{6}$ B) 0 C) -∞ D) $\frac{1}{12}$ E) ∞. Only 254 (29.3%) students chose the correct answer D). Forty one students (4.7%) who got the answer zero, might have substituted 36 in the place of x and worked out the result as zero, although such a quotient was undefined. Factorisation also seems to have been a problem to the majority of students. In particular writing $x - 36$ as a product of the two factors $\sqrt{x} - 6$ and $\sqrt{x} + 6$, was not an obvious simplification for the majority of students. Dealing with a radical sign appears to have been more problematic for students than dealing with the concept of potential infinity (∞). Our study differs from the reported studies here in that student were not only expected to solve the tasks on limits, but were also to justify why their chosen methods were more preferred than others that may have qualified. In this way we managed to access students' thinking about the symbolism used through their written work.

THEORETICAL ORIENTATION: THE NOTION OF PROCEPT

Gray and Tall (1992) proposed the notion of procept (the duality of mathematical symbols as both process and concept) and argue that when students focus mainly on procedures, they may very well be good at computations and succeed in the short term. Such students will, however, lack flexibility of approach that is needed for long-term to succeed in mathematics. This (that is, focus on procedures) they suggest should be complemented by the global view of the concept. Figure 1 shows the spectrum of the stated outcomes of the constructs *pre-procedure, procedure, process, and procept* together with their levels of sophistication from the work of Gray and Tall (2001).

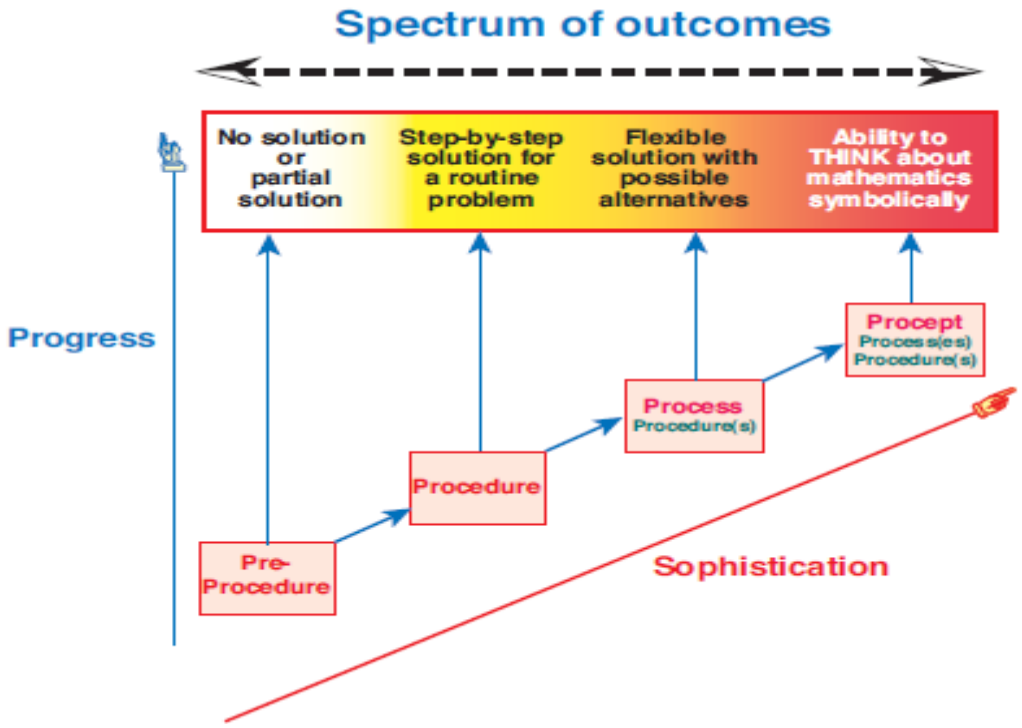

Figure 1. *A spectrum of performance* (Source: Gray & Tall, 2001, p.69)

As highlighted earlier, a *procept* is a combined mental object consisting of both process (series of procedures) and concept in which the same symbolisation is used to denote both the process and the object which is produced by the process (Tall & Gray, 1992). According to Tall (n.d), there are several different ways in which the symbolism is used, namely, (a) a *procedure* which consists of a finite succession of actions and decisions built into a coherent sequence. It is seen essentially as a step-by-step activity with each step triggering the next (or a specific algorithm for implementing a process), (b) *process*, this refers to when the procedure is conceived as a whole and the focus is on input and output rather than the particular procedure used to carry out the process (it may be achieved by *n* procedures and affords the possibility of selecting the most efficient solution in a given context), and (c) a *procept* requires the symbols to be conceived flexibly as processes to do and concepts to think about. Thus, the spectrum of procedure-process-procept is not a classification into disjoint classes because of the interrelations that exist between the three constructs (Gray & Tall, 2001).

Understanding limits using the procept theory

In what follows, we attempt to clarify the terminology used in Figure 1 by means of examples in the context of limits. The Pre-procedure stage is when the student has not responded to the task or has not completed the procedure in solving the task. Procedures in limits include the quotient rule, the product rule, the power rule etc. This requires students to perform routine mechanical steps which may be performed without understanding the concept behind such steps. Processes include $f(x) \to L$ and $x \to a$ which constitute part of

informal definition of limit. These processes differ from procedures in that they require the proper understanding of the concepts of "neighbourhood", "number" and "tending to" or "approaching". The choice of numbers in the neighbourhood of x is not done mechanically but with understanding of the number concept. Successive points (numbers) of x that tend to a also have to be chosen with understanding of the number concept. Identifying the limit value requires the coordination of the two processes $f(x) \to L$ and $x \to a$ meaningfully in order to come up with the correct limit value which may not be a number on the table of $f(x)$ values (if done numerically). This is because some calculations will have to be completed mentally, and careful analysis of the number that is being approached from both the left-hand side and the right-hand side by functional values be made through the coordination of $f(x) \to L$ as $x \to a$.

If an expression given is observed in totality (seen as an object) and is broken down through factorisation, for example, a judgement of which procedure to perform still needs some understanding of whether the resulting expression warrants direct substitution or not. The knowledge of how to find the limit of a polynomial function is necessary if such a case arises after the simplification. The restriction of not equating x to a is also necessary in the interpretation of the result of the limit value of the functional value. The notation $\lim_{x\to a} f(x)$ that represents both the process of *tending to a limit* and the concept of the *value of the limit* is a procept. A specific example that could be considered is $\lim_{x\to 2} \frac{x^2-4}{x-2}$, which represents both the process of tending to a limit and the value of that limit, 4. In this case the object, $\frac{x^2-4}{x-2}$, is decomposed by the process of factoring to $\frac{(x-2)(x+2)}{x-2}$ if chosen. Through simplification this leads to finding the expression, $x + 2$, provided $x \neq 2$. The new function which is now a polynomial allows for the direct substitution of the number 2 to produce 4. The 4 which is the limit value is obtained by adding 2 to 2. The flexibility of decomposing the function leads to a composition of adding the numbers by following the rules of limits.

The order in which the x values are chosen is also important in infinite limits and the simplification of expressions requires a good judgement as to whether some parts will tend to zero or not by following a procedure of dividing by the highest power of the variable in the denominator. For example, in finding the limit of $\frac{2x^3+x^2+4}{3x^3}$ as $x \to \infty$, dividing each term (numerator and denominator) by x^3 yields $\frac{2+\frac{1}{x}+\frac{4}{x^3}}{3}$ which becomes $\frac{2}{3}$ since the other terms tend to zero as $x \to \infty$ when applying the rules of limits. To some students it may not be so obvious that the terms that lead to zero may be left out and so they may equate the limit of $\frac{2x^3+x^2+4}{3x^3}$ as $x \to \infty$ to the limit of $\frac{2x^3}{3x^3} = \frac{2}{3}$ as $x \to \infty$. This is only done taking into consideration the process of tending to which now excludes the limit operator, $\lim_{x\to a}$. That is, $\lim_{x\to a} \frac{2x^3+x^2+4}{3x^3} = \frac{2+0+0}{3}$ (The zeros should not be written before the process of simplification is completed). These procedures and processes lead to finding the limit value, the object. The given

examples do show that the three constructs procedure, process and procept are indeed not mutually exclusive.

In order to understand why the students viewed the symbols as either processes, objects or procepts, we added an element of letting them justify their answers. This is an element that is lacking in the Procept theory, hence we had to make some changes that would accommodate this element. The adjusted framework also includes where learners have committed errors at various levels of the level of sophistication of the outcomes.

RESEARCH DESIGN

The study followed a case study design which is exploratory in nature. The purpose was to collect qualitative data that will reflect how students understand the symbolism used in limits at different levels of sophistication of the procept theory (procedures, processes or procepts). In addition, students were to solve problems which will reflect their understanding of procedures and processes employed in the computation of the limit values. The methods that were used by students were accompanied by an explanation of why such method was preferred to others that were also appropriate for solving the given task. Very little quantitative aspects that appear in data analyses to create a meaningful whole are complementary to the qualitative results which are more dominant (Starman, 2013).

The sample and data collection techniques

The sample was a group of 60 first year social science students who were registered for Bachelor in Economics and Certificate in Statistics. This group took a Calculus 1 course for non-mathematics majors. They were introduced to calculus for the first time at the university after having completed a course in algebra during the first semester. As indicated earlier, students require to understand the concept of limit in order to tackle problems in their field of specialisation because of its applicability in concepts such as marginal demand, marginal supply, marginal propensity to consume and save, etc. These are some of the concepts which pave way to the understanding of more complex ideas in both micro and macro-economics. Data were collected by letting students solve mathematical tasks. They also needed to provide a justification for the method(s) used. The teaching of the group comprised three lectures per week. The lectures were complemented by a 2-hour tutorial session per week. Each tutorial tested the students' understanding of the content covered in class. In the tutorial sessions, students were divided into smaller groups. Data was collected after nine lectures which were completed in three weeks. This was done during the lecture period. The writing time took one hour under the supervision of the lecturer (the first author) to avoid any discussions that may take place among the students in order to get a more valid data.

The Tasks

The students were given three main tasks to respond to. These were in some cases complemented by sub-questions which required them to reflect on their thoughts as they

tackled the tasks or to explain their answers. In Table 1, we provide details of the tasks and the justification for each task in a tabular format.

Table 1. Written Tasks and justification for Task selection

	Tasks	Justification
1	Do the expressions $f(x) \to L$ as $x \to a$ and $\lim_{x\to a} f(x)$ mean one and the same thing? Explain your answer.	This task was asked in order to investigate if students could tell that the symbolism used in the expressions mean one and the same thing even though the first has the dynamic feel while the second seems static. In addition, they were asked to explain their answers to see the type of conceptions that the students had about the symbols in the manner in which they were presented (that is, whether they see a symbol as process, concept or procept)
2	Find $\lim_{x\to 3} \frac{x^3-27}{x-3}$. (i) As you responded to Question 2, what thoughts, questions or ideas came to mind as you were answering the question? (ii) Do you know any other methods besides the one(s) you have used which can be used in answering the question? Mention those other methods (if any). (iii) If yes (in ii above), why did you choose the method/methods you used as opposed to others (iv) If no (that is, if you don't know of any other method), say why you think there is only one method to solving the question.	This was to see if the students would follow the correct procedures in solving the problem step-by-step and/or if they would look at the function in totality and act on it accordingly. Looking at the function in totality required the students to break it down into simpler and manageable components and factoring before substitution as the resulting expression would be a polynomial (and then compose the result to a limit value). The sub-questions were added to see if students chose the methods on the basis of promoting understanding or efficiency in terms of saving time.
3	Is $\lim_{x\to\infty} \frac{8x^3+5}{2x^2+1} = \lim_{x\to\infty} \frac{8x^3}{2x^2}$? (i) If yes, why do you think so? (ii) If no, why do you think so?	For this task, the students were to respond to the sub-questions to see if they would be able to tell whether the steps carried out in solving such a problem are understood in the context of limits or not.

Methodological approach

In developing categories that would guide our analysis we devised the table adapted from the work of Gray and Tall (2001) in Figure 1 which shows *a spectrum of performance* that reflect the sophistication of thinking of the student (the spectrum starts with pre-procedure, procedure, then processes and ultimately the proceptual conception).

In our study, we noted that there were students who attempted some questions but used the incorrect procedures or processes to arrive at an incorrect answer. In addition, in some cases where the symbolism was observed as proceptual, the reasoning behind such an answer was faulty. These three categories are not included in the procept framework. So, in our study, we have added three extra categories (levels 1, 3, and 5) to the procept framework (as shown in Table 1) to accommodate these missing elements:

Table 2. Categories, descriptions and indicators for data analysis

LEVELS/CATEGORIES	DEFINITION/DESCRIPTION	RECOGNITION RULE/INDICATOR
Level 0: Pre-procedure	When no solution or partial solution is provided for a question.	This is a situation where the student leaves the question blank without providing a solution or where a student does not complete the response to the question
Level 1: Erroneous procedure	When the solution provided by the student is incorrect due to failure to execute the procedure accurately.	This is a situation where the procedure followed by the student is not accurate or correct.
Level 2: Procedure	The particular method(s) (sequence of steps) used accurately by an individual at a given time to solve a particular mathematics question	Sequential steps followed being correct or accurate.
Level 3: Erroneous process	The incorrect assumption that a question is a particular mathematical process	When a student thinks that a question evokes a particular mathematical process, albeit, erroneously. This is the stage whereby a student will implement the procedures at different stages of the process but does not master the input and output conception of a process.
Level 4: Process	When students are able to solve a mathematics task in a variety of ways but focusing on the input and the output.	Did the mathematics flexibly and efficiently without errors. The focus here is on the input and the output rather than the

		individual steps or procedures along the way.
Level 5: Erroneous procept	When dualism of symbolism is observed without proper understanding.	When dualism of symbolism is observed but incorrect explanation or working is displayed.
Level 6: Procept	When dualism of symbolism is observed.	Observing the duality of mathematical symbols as both a process and a concept/object.

RESULTS

The presentation of the results follows the order in which the research questions appear in the paper. The research questions read: (1) How do Social Science University students understand mathematical symbols representing the idea of limit? (2) What methods or techniques do they employ in solving mathematical tasks on limits? And (3) What justification(s) (if any) do students give for a preferred method in solving tasks over the other? The first research question is answered in two tasks (Tasks 1 and 3) that represented the idea of limit using symbols. As highlighted earlier, the two tasks were analysed using different parts of the theoretical framework, hence their results will be presented in two parts, (a) and (b).

(a) **Students' understood the mathematical symbols representing the idea of limit as non-proceptual, erroneous proceptual or proceptual**

When asked in Task 1 if the expressions $f(x) \to L$ as $x \to a$ and $\lim_{x \to a} f(x)$ mean one and the same thing, 28 (≈46.7%) students said no, while 32 (≈53%) students said yes. Students who said no were classified as not having a proceptual conception of the symbolism used. Of the 32 students who said yes, 7 (≈11.7%) of them backed up their choice of answer with faulty explanations. These students who said yes with faulty reasoning were classified as having an erroneous proceptual conception while those who gave mathematically correct reasoning were classified as having proceptual conception of the symbolism. Some of the responses belonging to the mentioned categories follow:

Non-proceptual

Student 31 below is representative of students who said 'no' in Task 1:

S31: They do not mean one and the same thing because if they were the same they would both be limits but $f(x) \to L$ as $x \to a$ is not a limit. $f(x) \to L$ as $x \to a$ means that $f(x)$ is approaching a limit as $x \to a$ while $\lim_{x \to a} f(x)$ is a limit function itself.

S31 explicitly says that $f(x) \to L$ as $x \to a$ is not a limit. This means that he does not perceive the symbolism as representing the limit as the concept but a process since he says that in this

case the function is approaching the limit as $x \to a$. He refers to the symbolism $\lim_{x \to a} f(x)$ as the limit function and not as the limit. The two symbolisms are classified as the process and the concept respectively, although with an inaccurate technical terms. As highlighted earlier, it could be because the first has the dynamic feel while the second has the static one. Hence, they are not observed both as procepts.

Erroneous proceptual

An example of erroneous proceptual explanation is provided by student 22:

S22: $f(x) \to L$ as $x \to a$ mean one and the same thing because letters are being used interchangeably. So $f(x) \to L$ can be written as a form $x \to L$ and $x \to a$ in the form $f(x) \to a$.

In the erroneous proceptual conception, the use of symbols seems to be a major problem in terms of interpretation. The symbols are just used in such a way that they do not make sense at all (S22). This may be a generalisation about the use of symbols emanating from some mathematical contexts where symbols are used arbitrarily. For example, in calculus when writing functions, letters used are not restricted to only one variable; we may have $f(x), f(t), f(w)$, etc. depending on the relevance of the variable. either in the expression or the equation.

Proceptual

Finally, students 44 can be said to be on the proceptual level based on the response provided which is reminiscent of students in this category:

S44: They do mean one and the same thing but written in a different manner, that is, $\lim_{x \to a} f(x)$ is the limit of $f(x), L$, as x approaches a.

S3: Yes! Because the limit of $f(x)$ as x approaches a is the same as saying $f(x)$ approaches L when x approaches a.

The symbols used are said to mean one and the same thing. This means that each of them is seen both as the process of approaching and the concept of limit. Thus the students in this category have the procept conception of the limit symbols used.

(b) **Students' understood the infinite limits with constants as either equal to or not equal to the one without constants based on procedure**

When dealing with limits at infinity, as highlighted earlier, part of the procedure is to divide every term (in both the numerator and the denominator) by the highest power of the variable that occurs in the denominator, in this particular case x is such a variable, and every term that will end up with the structure $\frac{a}{x^n}$, (where a is a constant and $n > 0$) will tend to zero when x approaches infinity. Such terms can therefore be left out because zero is the identity element for addition and the expressions remain equal with the initial one without such terms. Some students may even go further to check the value of the limit whereas others may simply go

as far as the stated steps. Since the question needed mathematically sound reasoning, some students approached the problem from different perspectives.

Task 3 read: Is $\lim_{x\to\infty} \frac{8x^3+5}{2x^2+1} = \lim_{x\to\infty} \frac{8x^3}{2x^2}$?

(i) If yes, why do you think so?

(ii) If no, why do you think so?

For this task 46 students saw the two expressions as equal while 13 said that they are not (one student (S40) did not respond to the question). Four categories of responses were generated from the 39 out of 46 students and two categories were from 6 students out of 13 students, the other *7* gave individual responses. Of the 46 students, **7** of them gave individual responses. The reasoning given in most cases for agreeing to the equality of the two limit expressions were not mathematically sound or correct. Students who denied the equality of the two limits were already incorrect. Some responses demonstrating existence of these categories follow:

Yes, they are equal

The equality of the two expressions were based on the understanding that (i) limits of constants are zeros, (ii) adding a very small number to a large number has no effect or impact (iii) that the simplification of the two expression in dividing by a variable with a higher degree in the denominator leads to the left hand side function being equal to the right hand side one and (iv) that they have the same limit. Excerpts showing these erroneous procedure conception of understanding now follow:

(i) 5 and 1 are constants and their limit is zero [10 students]

S51: Yes they are the same because a limit of a constant is zero. 5 and 1 are constants therefore there is no limit.

This reasoning is not in line with how the limit value is attained or in comparing the two expressions. Thus the procedure for computing limits of this nature is not fully grasped, hence erroneous.

(ii) 5 and 1 have no impact [13 students]

S59: Yes, because as x approaches infinity the limit of the function won't be much affected by the constants 5 and 1, in the numerator and denominator respectively.

This is a rational function whose result depends mostly on the nature of the denominator. If it were a polynomial expression ignoring the 5 or 1 for x values tending to infinity would be reasonable in terms of their impact when added to large numbers but with regard to a rational function what is important is realising that when simplification is done the process of $f(x)$ tending to L, results in zero for those terms. This is the erroneous procedure level as the exclusion of 5 and 1 is based on the fact that when dividing by the highest power of the variable in the denominator the constant terms do not affect the results without explaining why this is the case. It is as if the limits of the constants are considered instead of the limits of their quotients when division by the variable with the highest power is performed on them when coordinated with the limit operator.

(iii) *They become equal after simplification* [9 students]

S42: Yes, because $\lim_{x\to\infty}\frac{8x^3+5}{2x^2+1}=\lim_{x\to\infty}\frac{\frac{8x^3}{x^2}+\frac{5}{x^2}}{\frac{2x^2}{x^2}+\frac{1}{x^2}}=\lim_{x\to\infty}\frac{\frac{8x^3}{x^2}+0}{\frac{2x^2}{x^2}+0}=\lim_{x\to\infty}\frac{8x^3}{2x^2}$.

S31: Yes, because according to the properties of limits while solving limits which are at infinity, we only use the variables with the highest power, and we exclude the constants.

When looking at the verbal response by S42 we could have concluded that the student is at the process level of understanding, but the working shows some flaws. The process of tending to the limit value is applied to some terms but not the others while the limit operator is still carried through. This is incorrect as the coordination of $f(x)\to L$ and $x\to a$ has to be performed simultaneously. S31's generalisation of excluding constants is also not backed up with any mathematically valid reasons. The realisation of their limits being zero when solving the tasks was a necessary justification in this case to show that the student understands the procedure of computing limits at infinity.

(iv) *They approach the same number* ∞ or approach ∞ [8 students]

S32: This is because they approach the same number

S9: Yes, because their answers both are approaching infinity.

S10: Yes. Both limits are approaching infinity and the highest degree of both functions are in the numerator that means both answers will be infinity.

S32 is the only student who referred to infinity (∞) as being a specific number while it is a symbol that is used when numbers outgrow the finite bounds. Getting the same limit value for any two expressions cannot be concluded to their equality (S9). This is because these are not the only two expressions in limits that result in ∞ as the answer (which shows nonexistence of the limit). To say that the limit approaches infinity (S10) is different from saying that the limit is infinity (∞). It is equally incorrect to say both their answers (S9 and S10) approach infinity without specifying that it is $f(x)$ that tends to infinity (∞). Thus, in this case also the procedure of obtaining limits at infinity has been erroneous.

No, they are not equal

Denial of equality of the two limits on the understanding that (i) dividing by the variable with the highest degree in the denominator produced different expressions for limits and (ii) that the expressions had different limits values.

(i) *Division by the highest power of the variable in the denominator* (x^2) *gives different results* [4 students]

S4: No, it is because when finding the limit of a number approaching an infinity, we divide by the highest power of the denominator and as we do so the results become $lim\frac{8x}{2}$ which is different from $\lim\frac{8x^3}{2x^2}$.

S16: The function because as we simplify the function it gives the different answer from the answer already given, $\lim_{x\to\infty}\frac{8x^3+5}{2x^2+1}=4x$ and not $\lim_{x\to\infty}\frac{8x^3}{2x^2}$.

In both cases the students are let down by failure to judge the equality of the resulting expressions. The students take $4x$ as the limit value which shows that they did not apply the limit operator on it to get ∞ as the answer. Thus, the procedure was erroneous.

(ii) *Different limits are obtained* [2 students]

S6: No, they are way too different because $\lim_{x\to\infty}\frac{8x^3+5}{2x^2+1}$ is 4 while $\lim_{x\to\infty}\frac{8x^3}{2x^2}$ is 0. So the two operations or equations are way too different. The other one approaches 0 while the other one approaches 4.

S58: No, because it doesn't make mathematical sense and $\lim_{x\to\infty}\frac{8x^3+5}{2x^2+1}$ is not equal to $\lim_{x\to\infty}\frac{8x^3}{2x^2}$ because when worked out they both give different result.

The denial for equality is already not a correct response. The first category of the no response has been separated from the second because in the first, students have clearly shown or said that they divided by the highest power of the variable in the denominator while this was not the case with the second category.

The students who said yes (the correct response) and the correct reasoning for this task would have been said to have reached the process and the concept level of the framework of analysis (performance outcome). This is because whether the question is responded to verbally or by a combination of carrying out the procedure(s) algebraically the student would still need to focus on the flexibility of getting the input and output by alternative means (Gray & Tall, 1994). Attaining the output requires both the knowledge of steps to be taken and the implementation of the coordination of the processes, $f(x)\to L$ and $x\to a$ in moving from the left-hand side to the right-hand side. While this is what we thought was the case, the reasoning did not match our judgement based on the yes response. Only one student, S40, who did not give any response was at the pre-procedure level. Students in the study of Maharaj (2016) also had problems with the computation of limits at infinity.

Methods used by students in solving tasks covered the adapted levels of sophistication of performance (from pre-procedural to process level)

The choice of how to solve a task depends very much on how the student understands the task the way it is presented (research question 2). The first part of Task 2 is presented. The sub-questions are discussed in the next subsection as their data gave answers to the third research question.

Task 2 (First part) read: Find $\lim_{x\to 3}\frac{x^3-27}{x-3}$.

In responding to this task, the two methods that were used are the numerical (table) and the algebraic. Each of these consists of a set of procedures to be followed and processes leading to the end result, the limit value which is understood to be an object/concept. Of the 60 students, 27 used the numerical (table method) while 33 used the algebraic method. Three students were at the pre-procedure stage because they did not complete their work.

Erroneous procedure level was achieved by 35 students. Twenty (20) students reached the procept stage. Students who reached the procept stage mastered both the procedures and processes that resulted in the correct output. Erroneous procept stage was achieved by 2 students who committed an error at when deducing the limit value at the procedural stage. All levels of outcome of the framework of analysis were realised. The excerpts that follow show these levels in students' workings (excerpt the pre-procedure level where the question was not attempted).

Erroneous procedure

S13: $\lim_{x\to 3}\frac{x^3-27}{x-3}=\frac{x\,x\,x-27}{x-3}=\frac{3^2-27}{-3}=\frac{9-27}{-3}=\frac{-18}{-3}=6$

The factoring of *x* was incorrect as it was not a common factor. The limit operator was also left out in the second step while *x* still existed as a variable.

Erroneous procedure and process

S41:	x	$f(x)$		x	$f(x)$
	2.9	26.11	3.01	27.0901	
	2.99	26.9101		3.001	27.009001
	2.999	26.991001		3.0001	27.00090001

It approaches 27

S41 did not clarify as to what approaches 27. It only became clear in his reasoning (presented in the next subsection) that 27 is the value that he thinks 3 approaches instead of the value being approached by $f(x)$. Thus the coordination of the processes, $f(x)\to L$ as $x\to a$, was faulty, hence the erroneous procedure and process as the output was not arrived at by proper reasoning. He realised that the substitution method did not work as the calculations produce 0 divided by 0.

Procedure and process

S55:	x	$f(x)$		x	$f(x)$
	2.9	26.11	3.01	27.0901	
	2.99	26.9101		3.001	27.009001
	2.999	26.991001		3.0001	27.00090001

27 Answer

S55 got all the steps correct (procedure within the process and the process in terms of input and output) that let to finding the correct limit value.

OR

S19: $\lim_{x\to 3}\frac{x^3-27}{x-3}=\lim_{x\to 3}\frac{(x-3)(x^2+3x+9)}{x-3}, x\neq 3=\lim_{x\to 3}x^2+3x+9$ = 27

$$(a-b)(a^2+ab+b^2)$$

$$(x-3)(x^2+3x+3^2)$$

All the steps taken to getting the limit value by S19 are correct. Thus, he qualified to be classified under the process level in terms of input and output

The choice of methods for solving tasks was based on appropriateness, accuracy or efficiency

In solving the tasks on limits there are some rules or procedures that one must follow depending on the nature of the task. It is not every method that can be applicable to all situations. Such a choice requires some understanding of why one method is more appropriate to use than the other known methods to a given situation. In this study, the students explained their choice of methods according to suitability or appropriateness to the task or their efficiency. Supplementary questions to the choice of method were posed in Task 2. This part is an attempt to answer research question 3.

Twenty-seven students who used the numerical (table method) said that this method is reliable while 32 out of 33 students who used the algebraic method said to be easier and it saves time. One student (S24) did not respond to these sub-questions. The students said that the numerical method is reliable because it allowed them to avoid getting 0/0 through substitution of 3 in the place of x in the function. Those who used the algebraic method argued that the method saves time as compared to the numerical method which they acknowledged to be the other method that they know. The excerpts of responses showing all the levels (pre-procedure to process in terms of input and output) of sophistication of the students' performance now follow.

Pre-procedure

S34:

(i) In substituting 3 for x the values would be divided by a 0. So if I don't then the $x-3$ are to move one another with the one on top making $x\neq 3$.

(ii) No

(iii) If I use the power rule, powers will be long since we have a numerator and the denominator $\frac{d}{dx}$may be hard to find.

The student was aware that substituting 3 for x would produce division by zero and did not know what to do next. Finding the limit value was however confused with finding the derivative by making reference to the power rule. Because of the given explanation, the student did not solve the given task.

Erroneous procedure

S13:

(i) What kind of method should I use? Should I substitute or make a table?

(ii) Table method

(iii) I chose substitution because I did not know how I was going to make a table even though my substitution gave me a problem, but I factored out xs ten divide there after I substituted with the 3.

The student is aware that she did not master the chosen method (procedure) but had problems with the table method.

Erroneous Process

S41

(i) I saw that when I substituted it came to a point where I get 0 and 0 divided by 0 is undefined. I saw that when I use the table, it gives me the values which are very close to each other.

(ii) Substitution method is the other method that I know.

(iii) I chose table because it gives me the exact value which 3 approaches.

S41 realised that the substitution method did not work as the calculations produced 0 divided by 0. He chose the table method because it gave him the value which 3 approaches. The reasoning is faulty as shown earlier. It is the value that the functional values are approaching that is the limit value. So, the input and output (process) connection is faulty.

Process

S55:

(i) I thought of substituting x with 3 but the answer I got was 0/0. I decided to use the table method.

(ii) Yes using algebra.

(iii) I used the table method because I forgot to break $x^3 - 27$ algebraically. So, I thought of the table as the next one.

S55 realised that the substitution of 3 posed some problems. Using algebra was also problematic for him by not knowing how to factor the difference of two cubes. We assume that this is what he means by breaking $x^3 - 27$ algebraically.

AND

S19:

(i) I thought of using the table then I realised that it takes long. Then I thought of factoring $x^3 - 27$ so $(x - 3)$ will be cancelled.

(ii) Yes, the table method.

(iii) It was easier and it saves time.

S19 seems to know the two methods that were applicable in this case, table and algebraic. He however chose to use the algebraic method on the basis that the table method would take him a longer time. Thus, the method (procedure) was chosen based on its efficiency.

DISCUSSION

For the first Research Question about how students perceive the symbols representing limits, we have found out that the symbols were perceived as non-proceptual, erroneous proceptual or proceptual. We believe that the students displayed such conceptions because in teaching such terminology is not made explicit but implicit which exhibits the students to truly conceptualise the symbols the way the framework suggests, proceptual understanding. The findings do overlap with the findings of Güçler (2014) which addressed the question: "How do one instructor and his students use and think about the limit notation in a beginning-level undergraduate calculus classroom?" (p.251). The findings of the study show that students perceived the limit as a process when using its notation, which is just part of the spectrum of outcomes of the Procept Theory.

For the second Research Question on how the students solved the problems on limits, our findings show that all the levels of sophistication of the adapted Procept Theory were displayed in the students' work, from pre-procedural to Proceptual level. The most difficult tasks on limits to solve were those that involved limit at infinity. Infinity as a notation, ∞, was problematic for students in the studies of both Maharaj (2010) and Jones (2015). We believe that this symbol which is used to show when numbers outgrow the finite bounds is very difficult for students to handle as it is something that cannot be shown on the real number line because of its metaphysical nature. Students also had problems with factoring. In this study, the factoring was that of difference of cubes while in the study of Maharaj (2010), the factoring involved the difference of squares involving radicals. As in the study of Denbel (2014), some students in the reported study thought only about the manipulative aspects and did focus on the idea of the limit. Some similarities also exist with the findings of Moru (2009) in that at the erroneous procedural level some students denied the existence of the limit where the function was not defined. This was concluded from getting 0/0 after substituting $x = a$ in the function. This was the same finding in the study of Denbel (2014). In both studies there are students who said that the limit is not being defined at the point, $x = a$, when it is actually the function that is not defined at that point

The students' choice of methods (Research Question 3) was based on appropriateness, accuracy or efficiency in terms of time and not necessarily in the way they perceived the symbolism from the framework of the Procept Theory as it was not part of their vocabulary. This part of allowing students to explain their answers was unique to this study, hence there is not comparison that can be made with other studies elsewhere.

This research has shown that as we teach limits we should explicitly use the language of the framework that is relevant to the idea being taught, in this case, the Procept Theory. On the

other hand it could be argued that since this is not the only relevant theory, it could inhibit the versatility of students' thinking. Moreover the students may not easily get accustomed to this complex terminology which may only have meaning to the mathematics educators as it falls within their field of study. This view is supported by the study of Güçler (2014) on how students think about the limit notation. The findings show that although the instructor explicitly differentiated between the process and the product aspects of the limit, students still perceived the limit as a process when using its notation.

Although the procept theory has been used as the main framework for data analysis, additions that we made in the framework seem to have allowed us to classify some responses which did not exactly fit into the original framework. This is one of the major contributions that this study has made. Another important aspect of the idea has been that of having access to students' thinking with regard to their choice of methods when solving the tasks on limits. The type of questions that the students asked themselves when responding to the task have definitely been useful in understanding why students responded to the tasks the way they did. It seems to have been important not only to the researchers but also to students who had to reflect on what they were doing so that they can learn to make choices consciously.

CONCLUSION

The findings of the study have shown that the Social Science students displayed all the conceptions described in the adapted Procept Theory, pre-procedural to proceptual. Students encountered some problems in solving problems on limits. The most difficult procedure for students was that of factoring difference of squares. Handling limits at infinity was also problematic as the symbol ∞ seemed to be too abstract for some. Seeing the symbolism of limits as both the process and the product was conceptualised by very few students. In some cases the errors were displayed in the language that was used to explain the answers. The errors showed that students did not only have problems in explaining the technical terms but they also had problems in naming the technical terms. This was indicative in the manner in which the students were supporting their choice of methods or in explaining their answers. We would suggest that conducting more studies that focus on the language of limits, which is not necessarily confined to algebraic symbolism would be of great help to understanding students' conception of limits. Thus it could be a step in the right direction on how limits together with the associated language and symbolism can be used in teaching.

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THE IMPLEMENTATION OF PROJECT-BASED LEARNING MINI-RESEARCH TASKS ON STUDENTS' LEARNING OUTCOMES DURING THE PANDEMIC

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ABSTRACT

Statistics for Research Education is an important course for students in the Faculty of Education. Serious problems are experienced by students learning statistics, one of them is because the learning outcomes are not optimal. To overcome this problem, a lecturer can provide mini-research tasks. Mini-research is one form of assignment from project-based learning. This research was descriptive qualitative research. The subjects in this study were students from Cohort 2019 who took Educational Research Statistics courses. Learning activities and mini-research assignments are handled fully online. By giving students a mini-research assignment, students can be encouraged to learn statistical theories and concepts. Through mini-research tasks, students can increasingly see the big picture and interrelationships between topics in this course. The positive responses can be seen from students' reflections and results of the review given to the paper. The use of project-based learning with a mini-research task is an interesting idea and suitable for students. In addition to better student learning outcomes, students also become more conscious of the problems around them. Prospective teachers can learn to make research an upcoming provision when they enter the field of teaching.

Keywords: learning outcome, mini-research, pandemic era, project-based learning

INTRODUCTION

Educational Research Statistics is one of the subjects given to Pelita Harapan University Teacher College students. This course invites students to see the principle of God's truth in educational research. The content in this course is related to statistical theories and their applications in research, including understanding various statistical terminology, types of data, types of data distribution, data processing, data analysis, hypothesis testing, drawing conclusions, and interpretation of data. According to (Arnold, 2013), statistics explore the use of patterns and relationships in data. These two disciplines are related, but they use different ways of thinking and solving problems. Statistics is a way of thinking about data and working with them to answer substantive questions (Fienberg, 2014). Statistics is a branch of mathematics that has many benefits, including for prospective teachers. A teacher needs to have statistical skills to process data and present data. In addition, a future teacher should develop their abilities through research activity. Research conducted by teachers is expected to help teachers improve their learning quality. Statistics is a complex subject to learn. In statistics, some theories can be put into practice in conducting research. Educational research

statistics, which are taught at Universitas Pelita Harapan Teachers College, equip students to conduct special research in an education field. Thus, students are expected not only to understand theoretically but also to be able to practice the knowledge gained in conducting research.

Based on previous teaching experience, there were students' conceptual errors when working on several educational research statistical questions (Dirgantoro et al., 2019). If given a different question from the example, students feel confused and do not know what to do in working on the problem. Students do not understand the systematic steps in research. It can be seen from the results of the students' mid-semester exams, which showed an unsatisfactory score with an average score of 69.44. A solution that can be used to overcome the problems above is the Project-Based Learning model. Project-Based Learning is a creative, innovative, and contextual learning model which gives students the freedom to design and create a project from learning materials (Nugroho et al., 2019). The advantage of the Project-Based Learning model is that it can provide opportunities for students to build knowledge and develop their skills (Anggreni et al., 2019), besides that, students' critical thinking skills can also be improved (Astri et al., 2022). Project-Based Learning has many types of assignments. An assignment that can be given is mini research. The mini-research project is designed to be a form of simple research project-based learning in which students contribute dominantly, starting from research design, research implementation, and reporting research results in a scientific presentation (Haryono & Adam, 2021). Through this mini-research, students can learn to do research and write good scientific papers.

The problem of learning outcomes is significant because this will affect the students' achievement index. For this reason, students need to actively participate in learning, especially in online learning. Project-Based Learning is suitable as an alternative to online learning, because in the first semester of the 2021/2022 academic year at UPH Teachers College, online learning is still applied due to the Covid-19 Pandemic. Thus, it was found that there was a harmony in using Project-Based Learning to address student learning outcomes in the context of online learning during the pandemic. The expectation of the use of Project-Based Learning model is student learning outcomes will be better. It is easier for students to acknowledge the concepts in Educational Research Statistics courses and to practice the knowledge gained in conducting research. Therefore, the purpose of this research is to describe the implementation of Mini-Research Project-Based Learning on student learning outcomes during the pandemic.

LITERATURE REVIEW

Project-Based Learning

Project-Based Learning (PjBL) is a learning method that involves students constructing their knowledge through project completion or product development (Guo et al., 2020). Through this process, students are trained to find the solutions to authentic problems given through a process of knowledge integration, application, and construction (Guo et al., 2020). In its application, PjBL will require time, as well as the interaction between fellow students, as well as between students and teachers (Asan, 2005; Koparan & Guven, 2014). It means

that the learning process using PjBL can provide space for students to learn independently, strengthen conceptual understanding, and provide space for students to collaborate with fellow students. Through PjBL, students will collaborate in groups, and develop skills in planning, organizing, negotiating, and making consensus on task issues that are collected and presented scientifically (Noviyana, 2017).

Minister of Education and Culture, Nadiem Makarim suggested teachers try Project-based Learning during the Covid-19 pandemic (GTK, 2020). The Minister of Education and Culture believes that with Project-based Learning, the principle of cooperation will manifest in teaching and learning activities. By implementing PjBL, students are trained to be responsible, challenged, collaborate, learn to work together, and grow the ability to encourage (motivate) others. The characteristics of PjBL include: 1) task completion is carried out independently, starting from the planning, and preparation, to product presentation stages; 2) students are fully responsible for the project to be produced; 3) the project involves the roles of peers, teachers, parents, and even the community; 4) train creative thinking skills; and 5) the classroom situation is very tolerant of the lack and development of ideas (GTK, 2020).

The results of previous studies show that PjBL can help students in learning. Research (Koparan & Guven, 2014) explains that PjBL increased students' attitudes towards statistics in the intervention group. The implementation of PjBL during the pandemic has also been proven to be able to help students to be active and innovative, increase student motivation, increase student and parent collaboration (Sukmana & Amalia, 2021), and improve student learning outcomes (Fahadah et al., 2021; Misidawati et al. al., 2022).

Mini Research

Mini research is a form of giving assignments in learning. Mini research is identical to free inquiry (Permari, 2016), which encourages students to identify problems and then find solutions to these problems through experiments. The Ministry of Education and Culture (Wardani & Kurnia, 2019) stated that through mini-research, students are facilitated to independently design projects to be implemented so that students can explore, assess, interpret, synthesize, and provide information. Students can directly carry out research but with a narrower context. Before carrying out the mini-research, students are given stages as a guide. The stages of implementing mini-research (Kusumawardana & Dintarini, 2021) include: 1) determining the research theme, 2) determining research hypotheses, 3) distributing online questionnaires, 4) processing data using SPSS software, 5) processing data and interpreting research results, and 6) report generation. In this study, the stages of implementing mini research consist of 1) determining research topics related to education, 2) designing research flows, 3) compiling research instruments, 4) collecting research data, 5) processing research data, and 6) interpreting research results, 7) make a report, and 8) present the results of the mini research.

Mini research activities can help students improve their competence. The results of previous research stated that mini research activities can improve science process skills (Permari, 2016), increase the ability to master conservation biology material (S. Leksono,

2016), improve student learning outcomes, change attitudes, skills, values, behavior, and beliefs towards nature (Daulae et al., 2018), and has a positive effect on the ability to analyze problems (S. M. Leksono et al., 2020). Meanwhile, other research results state that the implementation of mini research in statistics courses can have a positive impact on students' mathematical interpretation abilities (Kusumawardana & Dintarini, 2021).

Students' Learning Outcome in Pandemic Era

In the pandemic era, learning activities were very limited. The learning environment must change. Students who initially study in schools where environmental conditions have been made in such a way as to support learning activities, now have to be carried out from their respective homes. The learning environment is indicated to have a considerable impact on student learning outcomes (Nurastanti et al., 2019). This means that the student's learning environment at home also needs to be adjusted to support student in learning. But in reality, not all families can provide this for students. Many students' have unsupported environment to carry out learning activities. In addition to environmental conditions, other factors that also influence learning activities, especially online learning are supporting facilities or infrastructures such as the availability of electricity, internet networks, and supporting devices. In Indonesia, the internet network is not evenly distributed throughout the region. The difficulty in accessing the internet and unsupported devices make it difficult for students to access online learning.

These factors can affect student achievement in learning become not optimal. This happens not only at the elementary school level (Kurniasari, Pribowo, & Putra, 2020), secondary school (Mauliddiyah & Wulandari, 2022; Pratomo & Gumantan, 2021), but also in higher education. To overcome this, there are many ways that teachers have tried to improve student learning outcomes during this pandemic, including through learning methods (Elkhatat & Al-Muhtaseb, 2021; Özhan & Kocadere, 2020), learning media (Octaberlina & Muslimin, 2020; Wichadee, 2017), as well as giving interesting assignments (Wajong et al., 2020). During the pandemic, students experienced learning loss. Students feel bored if learning is done online. Therefore, students need project-based learning. Giving projects to students can make them more enthusiastic about participating in class. Student scores during online learning can be said to be quite good, but not optimal because of several inhibiting factors. Students are disturbed by environmental conditions, so they don't concentrate when learning.

RESEARCH METHODOLOGY

The method used in this study is a descriptive qualitative method and supported by quantitative data to show student's learning outcomes after the teacher applies the Project-Based Learning model. The data used for this research is data on student learning outcomes in working on mini research projects. The sample used was the 2019 Teachers College UPH students who took Educational Research Statistics courses in the odd semester, namely Indonesian Language Education, Social Sciences Education, Economics Education and Christian Religious Education study programs with 96 students. Students are divided into 22

groups. Each group consists of 4-6 students. In groups, students as respondents in this study will work on the assignment by making mini research, which is collected in paper form, then the paper will be presented. Since the learning process is finished online, the presentation is recorded and uploaded on YouTube. Next, students listen to each other's presentation videos and then ask to give a review of their friends who are presenting, followed by filling in peer assessments and giving suggestions for the improvement of their papers. The problems raised in the mini research are problems that are selected based on the results of discussions in groups, according to the interests of students in research. The problems raised are topics related to daily life and exist around students. Each group is expected to raise a different problem so that the results obtained are varied and complementary.

The objectives of qualitative research include: (1) describing objects; it needs to be described through photographing, video, illustrating, and narrating. This depiction can be done on objects in the form of events, social interactions, religious social activities, and so on. (2) exploring the meaning behind the phenomena; the meaning behind the phenomenon/fact can be revealed if the researcher shows and reveals it through deep interviews and participant observation. (3) explaining objects; phenomena that appear in the field are sometimes not the same as what is the goal, become the core of the problem or in other words appear different from the main purpose, so that a detailed, detailed, and systematic explanation is needed (Setiawan & Anggito, 2018). This qualitative research is certainly different from quantitative research, because qualitative research does not use statistics but through data collection, analysis, and then interpretation (Fadli, 2021).

RESULTS AND DISCUSSION

Mini research projects are given to students in groups at the first meeting, when the lecturers and students discuss the RPS (Semester Learning Plan). It helps students to understand and prepare for working on this project. Students are given chance to choose the research topic or theme they want. It will help develop students' awareness to changes or problems that occur around them, especially during the pandemic they are currently facing. After students agree on the research theme, students need to consult with the lecturer. Figure 1 shows an overview of the process of making mini research that needs to be done by students in groups.

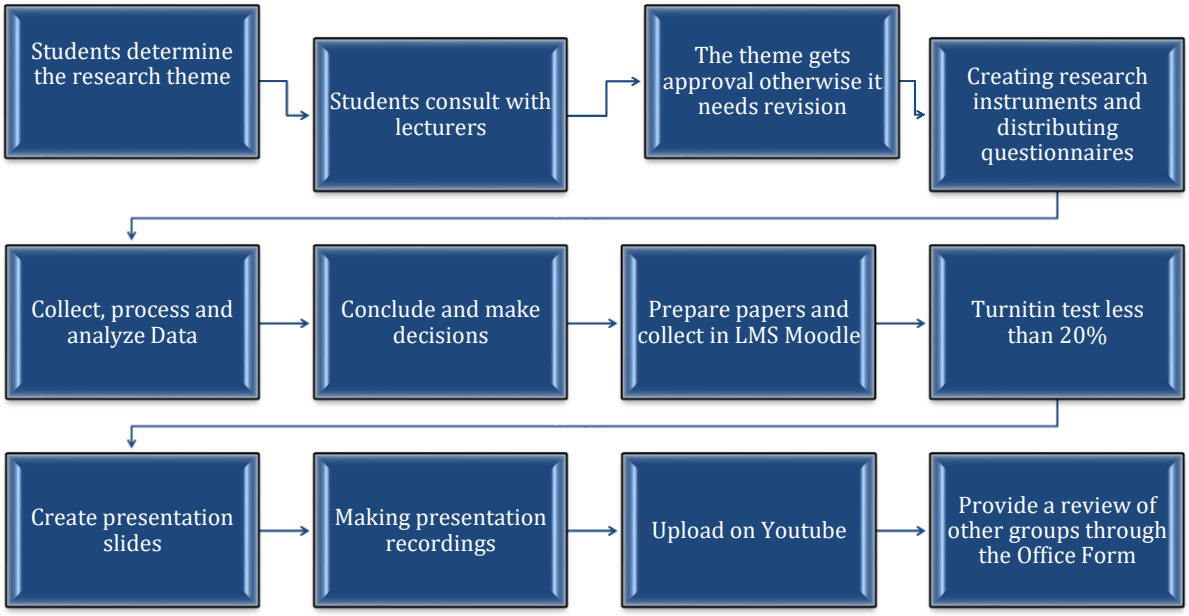

Figure 1. The learning process with Project Mini Research

After students choose a topic and determine a research title, then students collect theories related to the research title. Students begin to develop the background and supporting theory and determine the statistical hypothesis tests needed in their research. Next, students develop appropriate research instruments, collect data, process data, analyze data, make conclusions, and make decisions. It helps students in connecting concepts and theories that have been studied during one semester. The results of the mini research project are reported in the form of a paper and presented. The template or paper format has been provided by the lecturer and circulated before the division of mini research tasks. The presentation of the mini research project is done by recording the group presentation, then uploading it to YouTube. The submission of mini research papers and video presentations was carried out before meeting 16. After all groups have submitted their assignments, each student listened to the presentation videos from other groups. The purpose is for students to learn from each other and share information. Then students review, fill in peer assessments, and give suggestions for the presenting group. At the end of the activity, students also write reflections on the work on the mini research project.

Table 1. Descriptive Statistics of Mini Research Value

Description	Values
Mean	86.94
Minimum	68.17
Maximum	95.64
Standart Deviation	7.76

From Table 1 the performance of students in completing mini research projects is good. The average score of students in preparing projects is 86.94 where this average shows a better score than the average score for the midterm exam. The minimum score obtained by students is 68.17 and the maximum score obtained is 95.64. In addition, the standard deviation obtained is 7.76 which understands the spread of the data is still quite good or the resulting value is quite varied. From the data obtained, students understand the research flow well enough so that they can work on mini research projects as expected in the rubric. Students can clearly describe the background and problem formulation as well as describe all research variables with a minimum of 3 reference sources. In addition, students also explain the sampling technique, population, and samples used in the study. In this project, students are required to use a minimum of 30 research samples in total. After determining the number of samples, students also explain the scale of the research data and present it in the form of tables, bar charts/histograms.

Next, students present all descriptive statistical data containing the mean or mean, median, mode, standard deviation, and other related matters. Students also need to make a hypothesis test that includes prerequisite hypothesis testing and statistical hypothesis testing. Furthermore, students also describe all assumptions or prerequisite tests that must be met. Students must clearly and correctly explain all steps and statistical analysis. Furthermore, students draw correct conclusions. Students also need to provide suggestions for improving overall research deficiencies. All bibliographies must be written using APA rules, Edition 6. After that, students attach the results of Turnitin checks with a similarity of less than or equal to 20%. Students also need to attach all statistical calculations and questionnaires used, both prerequisite tests and inferential statistical tests. And the last is a presentation with a duration of 10 minutes in the form of a recording.

After students complete their mini-research and listen to presentation videos from other groups, students reflect independently. From the overall results of these reflections, there are 7 aspects of insight obtained by students.

Table 2. Student Reflection Results After Learning

	Aspects	Insight from Students
1.	The nature of research	Students see the importance of doing research systematically and managing data properly so that they can get the right conclusions.
2.	Attitude in conducting research	Students realize the need for data to be managed and kept confidential properly as part of the responsibility of the researcher so that research data is not misused. Also, the importance of a thorough attitude in carrying out research, as well as honesty in processing data. In writing research reports, students are also reminded to have an attitude of integrity by writing complete citation sources. In addition, students also learn to use valid data to be delivered systematically.
3.	The role of statistics	Through mini research, students are increasingly aware of the importance of statistics and see more clearly the significance of statistics, not only in education, but also in everyday problems. Through different topics, students learn a lot about new things around them, which they were not aware of before. Examples are changes in learning methods, daily activities (eating, drinking, sleeping), and others that have changed during the pandemic, which can be seen and tested using

		statistics. Through different topics, students can see and learn different methods and ways of doing this mini research.
4.	Concept understanding	Students gain a more complete understanding of statistical material by conducting direct mini-research, namely in calculating descriptive statistics, determining hypotheses, selecting and conducting appropriate statistical tests, to how to make decisions and draw conclusions.
5.	Provision for the future	Students can see the importance of studying Educational Research Statistics to prepare them for the future as prospective Christian teachers. Students get a clearer picture in practicing the theory that has been described, especially soon for working on the final project.
6.	Role in the group	Through the provision of mini-research tasks carried out in groups, students learn to be able to work together better, be responsible for the tasks they are part of, and manage time more effectively in discussions. Students can see the importance of complementing each other in working on group assignments.
7.	Appreciate other groups	Through the variety of topics and presentations presented, students learn to appreciate each other between groups. Students also learn about the use of attractive and effective power points in delivering messages, as well as clear and attractive presentation methods.

In Table 2 above, through a mini research project, students can gain a lot of learning insights. Another positive thing is that students can find their problems around them and try to provide solutions to these problems. This statistics course is only 2 credits, so the material presented is only up to parametric statistics. Although the material is limited, students can try to learn independently from non-parametric statistics material. Initially, students thought that when the data was not normal or homogeneous, students assumed that their research had failed. Meanwhile, in statistics, there are several methods or statistical tests for abnormal data conditions. Through a mini research project, students can practice using the normality test using Lilliefors, then using the t-test, and Z-test for one sample and 2 samples with dependent and independent samples. Several groups also use the Wilcoxon Signed Rank test because the data is not normal. The material delivered for students does not include the Wilcoxon Test. From this, students are challenged to learn independently to find out solutions in their research. The topics discussed by students were the differences sleep duration, students' time spent during pandemic, students' quota usage, time differences in using social media such as WhatsApp/Instagram/TikTok, online shopping intensity, and height/weight differences. Between male and female students, the intensity of defecation, the intensity of the amount of water consumed every day, the intensity of exercise time before the pandemic and during the pandemic, and other topics.

Through the concepts taught in statistics courses, students can see patterns and regularities in systematic research. Students also become accustomed to using existing formulas because they understand the material. Research (Prabowo, 2012) states that PjBL can improve students' understanding of statistical problems, which is indicated by the achievement of performance indicators, namely that students can understand: 1) data; 2) data collection methods and their validity; 3) data analysis; and 4) accuracy. Through mini-research projects, students are trained to be able to use and connect any material that has

been studied so that it can be applied to solving the problems found. Through mini research projects, students can see that "all truth is God's truth" (Basinger, 2021), which reflects that every truth comes from God. The meaning of "All truth is God's truth" is that everything, including research results in Educational Research Statistics, is the absolute work of God. Students can do research because it is a gift from God, and in conducting research, students need to see that knowledge is from God Himself. So, this understanding directs students in the sense that everything that exists on this earth comes from the absolute truth, namely the truth of the Bible. The Bible truth referred to here is the Bible as it is taught in Christian churches. Through statistical studies of educational research, students can see that in conducting research, it is necessary to involve God's wisdom based on the Bible. God is the source and origin of knowledge of the truth in all areas of life. This means that humans must take responsibility for using truth as a tool in environmental management. Statistics is a tool that can be used to help humans find solutions to the problems that exist around them. Through mini-research projects, students are trained to be able to see problems and find appropriate solutions to solve them. Students also learn how to manage the data with full responsibility, honesty, and integrity. Statistics are a tool that can assist humans in managing the earth. However, in the wrong hands, statistics can also be a destructive tool. Therefore, God's wisdom is needed so that humans can use statistics wisely as a blessing to others and bring glory to God's name. And finally, with the assignment of mini research projects, of course, student learning outcomes get good results with an average of 86.96. As a result, statistics teachers can use mini-research assignments to help students learn more effectively.

CONCLUSION

Project Based Learning (PjBL) in the form of assignments through mini research projects can help achieve student learning outcomes in the Educational Research Statistics course. Students can learn independently in making scientific works and processing statistical data. In addition, students also realize that the research process is a God's gift that can be used wisely for the development of human life.

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USING THE REACT LEARNING MODEL TO REDUCE STUDENT ANXIETY IN LEARNING MATHEMATICS

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ABSTRACT

Mathematical anxiety is an emotional response to the entire mathematical activity that affects students' mathematical to psychological abilities. This anxiety is influenced by a variety of factors such as negative perspectives on mathematics, experiences of failing in learning mathematics and others. Research data obtained through questionnaire one Christian High School in Tangerang showed that class X social studies students experienced mathematical anxiety where students had difficulty concentrating, anxiety, unconfidentness, headaches when learning mathematics. Anxiety affects students' self-confidence and makes the learning process not optimal so it needs to be reduced. The selection of *the REACT* model as a solution to this problem leads to varied, contextual and collaborative learning. The purpose of this writing is to find out the application of the *REACT* model in reducing mathematical anxiety of X social studies students in the Absolute Value Equation material. The method used in the research is descriptive qualitative, where data is collected through questionnaires. The results obtained show that the stages in the *REACT* model, namely *relating, experiencing, applying, cooperating,* and *transferring* succeeded in reducing the anxiety of class X social studies students towards learning mathematics. During the application of the model students are seen concentrating while studying, confident, daring to ask questions and others. The application of the *REACT* model can be a solution for teachers to manage mathematical anxiety while leading students to realize their identity as an *imago dei* who has been reconciled to God in Jesus Christ. Students are endowed with a Divine capacity to do God's work. Reflecting on the implementation of the REACT model, the authors suggest recognizing the characteristics as well as collaborating the *REACT* model with other learning resources.

Keywords: mathematics anxiety, REACT model learning, Imago dei

INTRODUCTION

One of the internal factors of the student's psychological that influences the learning process of mathematics is mathematical anxiety (Muqorobin & Triana, 2022). Khasawneh, Gosling, & Williams (2021) convey that mathematical anxiety affects mathematical ability in various conditions both in everyday life and the learning process. Because, anxiety is a psychological response that is naturally apparent when faced with a problem (Faried & Nashori, 2013). In line with that, Saputra (2014) said that mathematical anxiety is a manifestation of feelings of anxiety, fear, dislike that arise when participating in mathematics learning.

Christianity does not turn a blind eye to the existence of anxiety in man. The Christian faith believes and realizes that such anxiety does not lead people to problem solving (Psalm 46). In the learning process, anxiety affects human design created as beings who have the ability and capacity to learn (Redgrave, 2002). Just as if the existence of mathematical anxiety leads students to avoid mathematical things, then students will never come to a problem solving. Awareness of this is only obtained if you have the knowledge of the great God and the helpless man (Adhinarta, 2021).

Christianity believes that God created man in His image (Gen. 1:26-27). God created and prepared man with a Divine capacity to do good works (Murray, 1901). Humans are created to have reason, high cognitive abilities and a moral character that can develop (Williamson, 2017). So it should be through the knowledge of God in Christ, that man realizes that anxiety is not a leader over his thoughts and actions. Sensitivity to the existence of anxiety that exists in oneself can lead humans, especially students, to the realization that in the process of learning there are still many things that need to be improved and developed.

Many factors that shape anxiety about mathematics are negative views of mathematics and mathematics teachers, poor learning experiences, insecurity and low mathematical ability of students (Africk, Tobias, Kogelman, & Warren, 1981). This is in line with the reality in the field where some previous research results show that there are still many students who do not like mathematics, consider mathematics difficult, impractical, boring and require a high level of ability to learn it (Siregar, 2017; Yeni, 2015). If the experience continues to occur both in the short and long term, a "vicious circle" will be formed which becomes a stimulus for the formation of anxiety about mathematics in students (Ramadan, 2019). As a result, even though the student has tried more, the effort will not work optimally to build his mathematical understanding. (Soleh, Candiasa, & Widiartini, 2014; Auliya, 2013). Mathematical anxiety can also lead students to avoid mathematical things which also include learning mathematics (Kristanti, 2009). Therefore, it is important to build a good interpersonal experience for students in learning mathematics.

As far as the interaction with class X social studies students during the implementation of field teaching practices on July 25 to August 26 at one Christian high school in Tangerang district, researchers suspect that they experienced anxiety in learning mathematics. The researcher then gave a questionnaire after conducting observations in the second week on August 08 to prove the presumption to X social studies students, which numbered 19 students. Referring to the results of filling in the mathematical anxiety questionnaire when studying the topic "Equations and Absolute Value Calculations of One Variable", it was obtained that 68.5% of students had difficulty concentrating, 68.4% of students expect failure of work related to mathematics, 68.4% of students experience confusion, 52.6% of students feel unable to solve math problems, 78.9% of students feel confident only when able to understand the material and solve problems, 52.7% of students refused to do questions in front of the class, 42.1% of students were afraid to ask teachers or friends, 36.9% were afraid while participating in learning, 42.1% of students felt restless while studying mathematics, 63.2% of students *overthinking,* 15.8% of students felt nauseous,

63.2% of students felt headaches while studying mathematics, and 73.7% of students experienced a rapid heartbeat while taking a quiz or n math exams. The above results show that X social studies students experience anxiety about learning mathematics and make the learning process not optimal so that it needs to be reduced.

The effectiveness of mathematics learning can be optimized by helping students reduce their anxiety about mathematics. According to Ramadan (2019) several things that can reduce mathematical anxiety are: (1) explaining the importance of learning mathematics, (2) fostering self-confidence by inviting students to practice doing problems together, (3) eliminating negative perspectives on mathematics by providing images and examples ranging from simple to complex related to the material studied, (4) teaching with various methods that can accommodate sharing learning styles students, (5) teach concepts instead of rote memorization, (6) create comfortable and fun classes and (7) cultivate a sense of responsibility for their success. Based on the explanation above, the REACT learning model is considered capable of being one of the right tools to apply these things.

The *REACT* model is a learning model with several stages, namely (1) *relating, experiencing, applying, cooperating,* and *transferring.* At the stage *of relating* students are directed to relate the material to previous knowledge or in a real-life context. In line with the statement of Cahyono, Sutarto, & Mahardika (2017) that *REACT* is a learning model that leads students to find the meaning of the lesson and see its relevance in everyday life. At the experiencing stage , students are taught concepts with various methods that are relevant to the learning context. This is in line with the results of research at Kemala Bhayangkari High School that the REACT model has proven to be one of the solutions in instilling students' understanding of mathematical concepts (Lestari, Sahputra, & Lestari, 2021). At the *applying stage,* students are given the opportunity to practice questions to apply the concepts that have been obtained. At the *cooperating* stage students are given a study room together with friends in a study group. According to Wahyuni (2016) learning that involves students actively and interactively with group learning is one way to create *joyful learning*. At the transferring stage , students are introduced to a new context in applying the concepts learned so that they can more clearly see the importance of studying the material. Looking at the entire stages of the REACT model, Wahyuni, Yati, & Fadila (2020) stated that all of the stages in this model are considered interesting and effective in achieving successful mathematics learning. Thus, these five stages can be used by teachers as *tools* to reduce students' anxiety about mathematics.

LITERATURE REVIEW

Mathematical Anxiety

Mathematical anxiety is a feeling that arises as a response to discomfort or emotional reactions when facing mathematical problems such as assignments or exams (Anugrah, Kusmayadi, & Fitriana, 2019). Agreeing with that, mathematical anxiety is a form of uncomfortable feelings towards mathematical activities (Rizki, Rafianti, & Marethi, 2019). According to Waheed & Mohamad (2011) mathematical anxiety is one of the factors that influence students' attitudes in mathematics learning. Mathematical anxiety tends to lead

students to avoid learning and not be able to learn mathematics (Tatiana, Pranuta Murnaka, & Wiyanti, 2018). This is because math anxiety is a form of students' inability to adapt to mathematics lessons which causes students to find it difficult to learn and feel unable to learn it (Anita, 2014). Thus, it can be concluded that mathematical anxiety is part of the affective realm in mathematics which appears to be a manifestation of uncomfortable feelings as well as a form of inability to carry out mathematical activities. If not managed properly, then students find it difficult to adapt and feel unable to learn mathematics. In line with the understanding of Fadilah & Munandar (2019) that this anxiety needs to be studied to improve the quality of learning because it makes students unfocused and difficult to accept and understand the teacher's explanation.

Some of the research results put forward the reasons that cause the formation of mathematical anxiety, namely students' mathematical backgrounds that are lacking, experiences of failing in mathematics, study habits by relying on formulas, applications and problems learned unrelated to real life, lack of concrete material exposure, personality types, negative approaches to mathematics, lack of confidence, fear of not achieving graduation criteria, and inappropriate feelings and thoughts from those around (Mutlu, 2019; Mutodi & Ngirande, 2014; (Africk et al., 1981)). According to Sari, Zakiyah, & Dewi (2021) a person's personality is a predisposing factor to the onset of anxiety. In line with that, Winarso (2014) said that the 4 personality types of students, namely choleric, sanguine, melancholy and sanguine affect the excretion of attitudes and behaviors when in a condition including in the learning process. These things will affect the cognitive, affective, behavioral and physiological realms of students in mathematics learning (Olango, 2016).

Istikomah & Wahyuni (2018) divides indicators of mathematical anxiety in the cognitive realm, namely difficulty concentrating, self-confidence, self-ability, expecting failure of the affective realm, namely anxiety and feeling nauseous, and physiological will experience dizziness, heart rate & excessive sweating. Diana, Marethi, & Pamungkas (2020) conveyed indicators of students experiencing mathematical anxiety if (1) the cognitive realm is difficult to concentrate and low self-ability, (2) the affective realm by feeling restless, *overthinking*, nausea, not enjoying mathematics, and (3) the physiological realm, namely headaches, cold sweats, faster heart beats. The same thing was also conveyed by Aprillia & Lestari (2022) that the indicators of mathematical anxiety are as follows, namely expecting failure, not being confident, anxious, nervous, palpitating, restless and not liking mathematics. Setiawan, Pujiastuti, & Susilo, (2021) also said that the indicators of students experiencing mathematical anxiety are fear to do something, not wanting to do things that have been done before, expecting difficulties, anxiety, confusion, difficulty breathing, faster heart rate, feeling uncomfortable. Based on the exposure to the theory of mathematical anxiety indicators above, the indicators that will be used in this study cover 3 domains, namely cognitive, affective, and physiological/somatic as follows:

Table 1. Math anxiety indicators

Domains	Indicators
Cognitive	Concentration
	Expecting failure
	Confused
	Self-ability
	Confidence
Affective	Fear
	Restless
	Overthinking
Somatic/physiological	Nauseous
	Headache/dizziness
	Fast heart rate

These indicators are the result of synthesis that has been presented by several experts with the consideration that they have been used by more than 2 experts in previous studies and the indicators can be identified by students through the signs experienced while learning mathematics through filling out questionnaires to see their anxiety.

REACT Learning Model (Relating, Experiencing, Applying, Cooperating, Transferring)

REACT is an acronym for *relating, experiencing, applying, cooperating,* and *transferring. REACT* is one of the learning models of the concept of contextual learning based on the philosophy of constructivism (Fatimah, 2022). In its application, the REACT learning model certainly has advantages and disadvantages. The advantages of the *REACT* model include: (1) the five stages are designed to build gradual understanding starting from the basic understanding at the *applying* stage to a deeper understanding at the *transferring* stage (Anas & A, 2018), (2) involving active student participation and linking learning to real-world contexts and (Putri & Santosa, 2015; Feby & Abadi, 2020), (3) designed to create a varied and fun learning atmosphere (Junedi & Ayu, 2018), (4) is collaborative to provide a broader understanding and build confidence by boldly conveying ideas and opinions in front of other students (Rizka, Syarifuddin, & Suherman, 2014) . In addition to some of the advantages above, this model certainly has disadvantages, including: (1) the difficulty of providing contextual examples in the context of everyday life (Selamet, Sadia, & Suma, 2013), (2) it takes a long time in its application and requires creativity, innovation and special communication (Riadi, 2022).

The *REACT* model is seen as a model that is able to involve the active participation of students in the learning process through its five stages, namely: (1) *Relating,* a learning stage that connects with previous knowledge; (2) *Experiencing,* stages that provide students with a learning experience that includes problem-solving and other activities; (3) *Applying,* implementing the concepts he learned by doing practice questions; (4) *Cooperating,* interacting with other students in the learning process; (5) *Transferring*, applying concepts in different contexts (Fauziah, 2010). COR (*Center for Occupational Research*) defines and

describes the stages of the *REACT* model, including the following: (1) *Relating* is a stage that connects the knowledge to be learned with students' understanding and circumstances in everyday life; (2) *Experiencing* is a stage that leads students to discover or explore basic concepts that require critical thinking through the inquiry method; *(3) Applying* is a stage that directs students to apply accepted concepts in solving mathematical problems and in everyday life; (4) *Cooperating* is a stage in which students learn together, share and communicate with each other with the aim of training the cooperation of teachers and students as citizens who essentially coexist with others; (5) *Transferring* is a stage that leads students to apply knowledge and experience to acquire new things (Fatimah, 2022).

Based on several theoretical studies regarding the stages of the *REACT* learning model, the stages that will be adopted and applied in this study are as follows: (1) *Relating,* students are given apperception questions that are associated with application in real life and practice questions to relate them to their previous knowledge; (2) *Experiencing,* a stage that provides space for students to try to recognize new concepts given through discussion of questions; (3) *Applying,* students apply new knowledge gained by solving contextual problems; (4) *Cooperating*, students are given space to discuss with the teacher or in study groups, (5) *Transferring,* a stage that directs students to solve problems individually in the form of *quizzes* or do independent exercises.

The Relationship of the REACT Model to Mathematical Anxiety

Mathematical anxiety correlates with students' mathematical abilities. Some studies state that students with low levels of anxiety have good mathematical abilities and are able to take responsibility for their tasks (Diana, Marethi, & Ultimate, 2020; Fani & Effendi, 2021). In addition, a competitive learning climate, less friendly teacher responses, irrelevant teaching and assignments, strict and rigid classroom policies or learning systems also cause anxiety in students (Yanti, Erlamsyah, & Zikra, 2013). Mathematical anxiety problems can be overcome by creating a varied and enjoyable learning process (Dwirahayu & Mas'ud, 2018). Varied learning can be seen in five different stages that can be filled with various activities according to the teacher's creativity that actively require student participation. In line with the opinion of {Formatting Citation} that each stage in the REACT model has a different activity where students are required to be actively involved, especially when the stages of experiencing students can explore inside or outside the classroom together with friends so that the learning atmosphere can overcome boredom. Nabilah, Umam, Azhar, & Purwanto (2021) added that mathematical anxiety can be overcome by creating a comfortable and pleasant learning atmosphere and presenting contextual learning by providing problems relevant to the student's situation. However, in the application of these five stages, it requires the readiness and creativity of teachers in designing activities, choosing the right topic that is more optimal if taught using the REACT model, especially in the experimental stages that require exploration and contextual examples according to the context of students, the environment, and learning tools and media (Ismaya, Subiki, & Harijanto, 2015)

The *REACT* model with its 5 stages is considered capable of being a solution to the problem of mathematical anxiety. The *REACT* model provides a space for all students to be actively involved in the learning process so that it becomes effective and meaningful learning that helps students understand and master concepts (Sinaga & Silaban, 2020). The *REACT* model supports the development of cognitive aspects when constructing one's own knowledge as well as relating previous understandings with new knowledge received (Dance & Rosana, 2019). The *REACT* model accommodates heterogeneous learning styles by providing space for active participation of students with their respective learning styles (Dewi & Utami, 2020). The *REACT* model is collaborative so that it can increase extrinsic motivation in the learning process (Nuraisah, Irawati, & Hanifah, 2016).

The *REACT* model has been proven to be able to improve the ability of mathematical processes that have been formulated by NCTM (*National Council of Teachers of Mathematis).* The application of the *REACT* model in class X science in one state school in Bukittinggi shows an increase in understanding of mathematical concepts and student confidence (Ramadhani & Jazwinarti, 2019). In addition to improving the ability to understand concepts, in their research Erwina, Jamal, & Hartini (2015) showed that the *REACT* model is successful in improving students' problem-solving abilities because in 5 stages it provides space for students to be actively involved in applying material in various forms of problems. The *REACT* model is able to facilitate in improving the problem-solving skills, mathematical connections and *self-efficacy* of students in class XI science at state high schools in Magelang rather than conventional learning models (Putri & Santosa, 2015). The application of *the REACT* model in mathematics learning is positively correlated with students' mathematical communication skills and self-confidence (Sapto, Suyitno, & Susilo, 2015). Furthermore, the *REACT* model successfully improved students' mathematical reasoning (Febryanti, Samad, & Wendi, 2021).

All of the results of the research and theory above show a correlation between the *REACT* learning model and students' mathematical anxiety. The REACT learning model has been proven to improve students' mathematical abilities. As well as one of the factors that affect mathematical ability is mathematical anxiety. In line with the results of research Anouti, Shehayeb, & Mchiek (2018) that mathematical anxiety does affect students' math performance. Students with good mathematical ability have low math anxiety. Thus, this presentation concludes that the REACT learning model is related to mathematical anxiety.

RESULT AND DISCUSSION

The REACT learning model is applied two times in 2 meetings consisting of synchronous and asynchronous activities carried out face-to-face in mathematics subjects in class X social studies during PPL 2. The material about absolute value discussed in the two meetings has only been known by students and has never been discussed at the secondary education level. According to the school system, teachers apply these five stages of the model in learning, namely the division of class modes into synchronous and asynchronous sessions. At the first meeting of the REACT model, the teacher started the lesson by praying, sharing positive energy in the classroom, saying hello, giving smiles, and inviting students to play

games to create a pleasant learning atmosphere. Then direct students to prepare for learning by preparing all learning equipment. The teacher also tells the learning flow, activities, and objectives of the learning activities to be carried out. Here is the implementation of the REACT model when implementing PPL 2 onsite in class X IPS.

Table 2. Proof of REACT model deployment

Session	**Stages**	**Implementation**	
		Meeting 1	Meeting 2
Synchronous	*Relating*	Provides apperception questions related to the definition of absolute value and its application in everyday life	Students do questions to remind the implementation of the basic concept of absolute value
	Experiencing	Students do six snatching questions in front of the class	Students recognize the properties of absolute value by working on questions
	Applying	The teacher gives each student a different question personally	Students work on guided exercises related to the traits of absolute value
	Cooperating	Students discuss privately with the teacher while going around to answer students' questions (*one-on-one discussion)*	In groups doing application questions
Asynchronous	*Transferring*	Students do the assignment and can discuss it with their friends	Students take quizzes related to the definition and characteristics of absolute value
Quiz	**Paper-based quizzes are done face-to-face in asynchronous sessions**		

The first stage, namely *relation*, begins by providing apperception questions related to the definition of absolute value and the application related to number lines. When the question was given, students said they were still confused by the question. The teacher tries to simplify again by explaining the concept of spacing on number lines using tiles. Only after being given 2 examples can students answer the question of apperception. This stage takes a lot of time, but it must still be done so that students understand the concept correctly and can move forward in the next material.

Giving apperception questions by relating previous knowledge and new knowledge as well as in a real-world context will build awareness, generate motivation and focus students' attention to participate in learning (Mariska, Kurniawan, Setyadi, & Fatmaryanti, Siska, 2013). If the student's attention has been focused on learning, it will help the student to concentrate. Concentration is a centralized attention to a certain thing (Nuryana, 2010). Furthermore, Sulastri (2016) said that the activity of linking learning with the real world helps students find the meaning of the material being studied so that they better understand learning.

In the second stage, namely *experiencing,* the teacher gives questions related to the application of the definition of absolute nia on the board and provides an opportunity for students to work on it in front of the class. Then at the second meeting with the learning objective of recognizing and applying the traits of absolute value, the teacher guides the students through the work on the questions. This activity is carried out with the aim of inviting students to develop their mathematical thinking skills. As a boost to enthusiasm, teachers give *rewards* to students who are willing to do it.

At the *applying stage,* students are given the opportunity to do practice questions independently which will later be discussed together. Students are asked to find an x grade by using the definition of absolute grade when working on independent exercises. Working on questions to find or apply a concept becomes more effective for improving memory than directing students to memorize (Saputra, 2014). The stages of *experiencing* and *applying* provide opportunities for students to construct their knowledge. Masitoh & Prabawanto (2014) said that by constructing their own knowledge, students will find it easier to understand learning and have an impact on increasing their mathematical abilities. Therefore, these two stages can be a solution to improve students' mathematical abilities.

At the second meeting of the application of this model, the teacher collaborated on the *applying* and *cooperating* stages in which students were asked to do questions in study groups of 3-4 students. In this study group, students are expected to share ideas with each other to solve problems. In addition, students who already understand are expected to be willing to teach concepts that are not yet understood by their other friends. This is supported by Sugiawan, Nurhanurawati, & Coesamin (2014) that group learning gives students space to share opinions, exchange ideas, help each other, and increase student motivation to understand learning. MZ, Rendani, Nainggolan, & Jannah (2018) also in their research said that cooperative learning with cooperation in groups overcomes students' anxiety because they understand that their friends have the same problem and form positive interactions during learning. This stage becomes a fun new color in the learning process. This is obtained from the reflection of students who state that "learning is difficult but fun". A pleasant learning environment affects students' sense of self-confidence, fear and anxiety in the learning process (Hannah, 2013).

The last stage in the learning process is *transferring.* At this stage, the teacher invites students to do contextual application questions independently and will later be discussed in groups. In this stage the active participation of students is very noticeable. Although there are some students who have not been able to do their own work, they are already willing to ask the teacher about things that are not yet understood. Students have also begun to get to

know the styles and ways of learning that are effective for them. Referring to the results of the reflection, there are students who say that it is easier to understand if the teacher explains it personally. This is accommodated when the teacher gives questions personally and goes around giving explanations for students who ask questions.

Analysis

This research uses a qualitative approach with observation methods to review student anxiety in mathematics learning. The instrument in this study is in the form of a questionnaire that has been used in previous studies by Anouti, Shehayeb, & Mchiek (2018). Then the statements in the instrument are modified according to the situation and context of the student and the student's learning environment using a Likert scale. Data collection is carried out online with the help of *google form.* The results of filling out the questionnaire conducted by 19 students were declared valid because each student only filled out the questionnaire once by choosing 1 option that describes what students have experienced in learning. Then, 1 week later students were given the same questionnaire and each of them received the questionnaire for the second time and obtained almost the same answer twice. Furthermore, the data is processed by dividing 2 categories, namely the percentage of students who choose the answer agree (A) and strongly agree (SA) means that confirming the statement has been experienced in learning and the percentage of students who choose the answer disagrees (D) and strongly disagrees (SD) will also be combined which means rejecting the truth of the statement happening to them.

Table 3. Percentage of anxiety before applying REACT

Indicators	Statement	Before (%)			
		A	SA	D	SD
Concentration	I have difficulty concentrating in learning math as much as it is difficult to focus, tend to forget what was just taught or at the previous meeting	21,1	47,3	26,3	5,3
Expectations Failed	I often expect to fail and will not get a passing grade when doing assignments, quizzes, or math exams	42,1	26,3	26,3	5,3
Confused	I tend to be confused about applying formulas when I want to do problems, confused about understanding mathematics because it is quite complex and less relevant to life	10,5	57,9	26,3	5,3
Self-ability	I feel unable to do math problems by myself, and find it difficult to understand some things related to mathematics	31,6	31,6	31,6	0
Confidence	I dare to ask a friend or teacher if I don't understand mathematics	15,8	26,3	42,1	15,8

	I feel confident only when I can understand the material and solve math problems	36,8	42,1	15,8	5,3
Fear	I am afraid to do the questions in front of the class if asked by the teacher	31,6	21,1	42,1	5,3
Restless	I feel restless during math learning	15,8	26,3	47,4	10,5
Overthinking	I am easily overthinking if I don't understand the material or math problems	42,1	21,1	26,3	10,5
Nauseous	I feel nauseous when I study math	0	15,8	42,1	42,1
Headache/dizziness	I feel headaches when studying or doing math assignments	42,1	21,1	15,8	21,1
Fast Heart Rate	My heart often flutters when I want to do quizzes or math exams	31,6	42,1	21,1	5,3

After obtaining the above results, the teacher saw that most of the students in class X social studies were shown to experience mathematical indicators of anxiety. Seeing this in the next 2 meetings consisting of *synchronous* and *asynchronous activities,* the author designed learning by applying the REACT learning model. On August 25, the teacher again gave a questionnaire with modifications to several statements that correspond to the implementation of the REACT model in the learning process, and the following results were obtained:

Table 4. Percentage of anxiety after applying REACT

Indicators	Statement	After (%)			
		SA	A	D	SD
Concentration	Learning mathematics like this really helps me to concentrate on learning	21,1	63,1	15,8	0
Expectations Failed	Mathematics learning that provides an opportunity to work on exercises together working in groups, conceptually and purposefully encouraged me to dare to try without focusing on failure	42,1	47,4	10,5	0
Confused	Learning mathematics with practice problems and examples of application in everyday life made me begin to understand its use and the stages of its work when doing problems	15,8	63,1	15,8	5,3
Self-ability	I better understood the concept of absolute value equation and began to be able to do absolute value questions because the learning was interactive, contextual, and collaborative	31,6	42,1	26,3	0
Confidence	I dare to try to ask a friend or teacher if I don't understand mathematics	26,3	42,1	26,3	5,3
	This kind of math learning fosters confidence that I have the capacity to learn math	31,6	42,1	26,3	0

Fear	I am afraid to do the questions in front of the class if asked by the teacher	5,3	26,3	57,9	10,5
Restless	I began to enjoy structured, applicative, and varied learning like this	57,9	42,1	0	0
Overthinking	Conceptual, directed, and collaborative mathematics learning helps me not to overthinking quickly when I am not able to understand or do problems	42,1	42,1	15,8	0
Nauseous	I feel that learning mathematics in this way makes me feel nauseous	0	10,5	52,6	36,8
Headache/dizziness	Learning math with a lot of activities like this gives me a headache	0	21,1	47,4	31,5
Fast Heart Rate	My heart often flutters when I want to do quizzes or math exams	10,5	26,3	57,9	5,3

After obtaining the answers before and after the implementation of the REACT learning model, here is the percentage change in the answers obtained:

Table 5. Accumulation of the percentage of decreased and increased in indicators of student anxiety before and after applying REACT

Indicators	Before	After	Increased (I)/ Decreased (D)
Concentration	31,6%	84,2%	I - 52,6%
Expectations Failed	68,4%	10,5%	D - 57,9%
Confused	68,4%	21,1%	D - 47,3%
Self-ability	31,6%	73,7%	I – 42,1%
Confidence	31,6%	71,5%	I – 39,9%
Fear	52,7%	31,6%	D – 21,1%
Restless	42,1%	0%	D - 42,1%
Overthinking	63,2%	15,8%	D – 47,4%
Nauseous	15,8%	10,5%	D - 5,3%
Headache/dizziness	63,2%	21,1%	D - 42,1%
Fast Heart Rate	73,7%	36,8%	D - 36,9%

In the first indicator there was an increase of 52.6%. Concentration begins to build at the *stage* where the teacher directs students to focus through the provision of apperception questions that relate learning to the context of everyday life. This is in line with the research of Mushawwir & Umar (2014) that giving apperception can foster students' attention, interest and concentration towards something, because the lesson must be built on pre-existing

knowledge. The second indicator showed a decrease of 57.9%. Through the application of this model, Christian teachers help students build a gradual understanding of concepts from the relating to the applying stage by providing apperceptions, explanations and practice questions independently or in groups, as well as providing an understanding that students must continue to strive and be humble in asking God for help to be able to do everything well. All things are God's gifts, not the result of man's efforts (Ephesians 2:8-9). In his research Zamili (2018) said that one way to overcome students who expect to fail in their abilities formed by failing experiences and viewing self-abilities as lacking is to integrate knowledge, skills and values in the learning process. Thus, it will build the student's confidence in himself that he will be able to do his duties and responsibilities.

The third indicator showed a decrease of 47.3%. The *stages of relating* and *applying* help students to find meaning and apply the knowledge they receive. Confusion can be overcome by leading students to understand concepts correctly so that later they are able to relate problems or mathematical problems given with mathematical symbols (Kholiyanti, 2018). Subsequently, the fourth indicator increased by 42.1%. The improvement of students' ability to learn mathematics is in line with research A and Anas (2018) that the REACT model helps students build mathematical understanding gradually from the applying to transferring stages so that it can streamline students' thinking skills.

The fifth indicator increased by 39.9%. Students feel more confident doing every class activity whether it's asking or answering questions. This is supported by the presence of teachers and friends in the study group who are willing to share with each other. The sixth indicator decreased by 21.1%. This fact is supported by the reflection and response of students during learning. In the midst of difficulties learning mathematics, students seem to be no longer afraid to participate in every learning activity. Students seem to be able to adapt and enjoy the learning process. This affected the physiology of students so that the percentage of students who felt restless (indicator 7) was 42.1%, *overthinking* (indicator 8) was 47.4%, felt nauseous (indicator 9) by 5.3%, dizziness/headache (indicator 10) by 42.1%, and a rapid heartbeat (indicator 11) by 36.9%. Summarizing the discussion above, it is known that the *REACT* model has succeeded in reducing students anxiety about mathematics learning. This is shown by a decrease in the percentage of students' mathematical anxiety in learning mathematics. These results are in line with the increasing active participation of students in participating in each learning activity.

As an *imago dei creation,* anxiety should not be the controller of human life. God, who created man, has the power to sustain and enable man in his weaknesses and limitations as a creation (Ferguson, 2002). The Fall in sin results in the distortion of God's image in man (Addai-Mensah, 2020). The damage includes thoughts, words, deeds and all aspects of the human being including perspectives that have deviated from the right thing (Driscoll & Breshears, 2020). The relation in mathematics learning is that sinful nature leads students to see themselves as a person who does not have enough ability to learn mathematics.

God gives special revelation of the person of Christ and the word of God to renew the image and likeness of God in man (Bavink, 2011). God's Word allows us to see God and all

existing realities correctly (Johnson, 2015). Christ's renewal affects the perspective of man, especially students, in seeing himself. By realizing reality as an *imago dei* that has been redeemed and bestowed with the word of God, students should be able to work on the abilities that exist within themselves and look at mathematics beyond numbers, formulas, symbols on paper, but through it increasingly see the majesty of God. In line with Jongsma's (2007) opinion that mathematics is part of God's work given to know God and see the beauty of His creation. With mathematics man can learn and explore God's creation through which he can also learn at a glance the character of God (Lowe, 2011).

The REACT learning model is one of the alternatives that can be used by Christian teachers to present mathematics learning that can accommodate student needs while maximizing their capacity. To find out these needs, it is necessary to have a relationship between teachers and students. An authentic relationship between teacher and student can only occur when the teacher perceives and accepts the student as a unique individual both emotionally, intellectually, spiritually, physically and socially (Johnson, 2015). In Christian education that makes Christ *Christ-centered*, teachers are enabled to view students as *imago dei* specially created and unique in these five aspects (Parinding & Tangkin, 2022). Thus, the learning process designed, especially mathematics learning, will direct students' eyes to see the process to equip students to do God's good work. Some of the important things that Christian teachers instill when applying this model are: (1) teachers and students always start learning by praying in a Christian way (2) teachers also instill Christian values in students just as students must always surrender and be humble to ask God for help in the learning process, not meme selflessness because everything comes from God, (3) at the stage of relating the teacher invites students to explore the work of God encountered in everyday life to see the learning more contextual and relevant to the student, (4) at the transferring stage also the teacher invites students to see the consistent and detailed nature of God in creating so that the concepts used in the equation of absolute value can be used to solve problems in different contexts.

CONCLUSION

The above study and discussion lead to the conclusion that the application of the model *REACT* With its five stages it can reduce students' math anxiety. First, at the stage *relating* the teacher guides students to relate the material learned to the student's initial understanding by providing apperception questions that are also associated with the context of everyday life. Second, *at the stage of experiencing* the teacher directs students to be able to experience firsthand the learning by doing practice questions. Thirdly, at the stage of applying teachers provide space for students to apply the knowledge that has been learned by doing questions. Fourth, at the stage *of* cooperating teachers give different questions to each student and hold *one-on-one discussion* for students who have obstacles. After that, the teacher also gave questions that will be discussed in the study group. Fifth, at the stage of *transfer* The teacher facilitates and guides students to apply the concepts learned in different problem contexts with the provision of varied applicative questions.

In the two meetings of applying this model, the decrease in students' math anxiety was also seen when students began to enthusiastically participate in every class activity, race to finish practice questions before class ended, and dare to ask teachers and friends during learning and during group study sessions. During the implementation of the *REACT* model in two meetings, there was a drawback, namely that this implementation took a long time because it had to adjust to the grasp of each student when participating in activities in each stage. Therefore, it is clearly seen that the *REACT* model cannot stand alone. The successful application of this model is inseparable from the role of a teacher, especially a Christian teacher. Looking upon the great God and man created in the image of God, enables teachers and students to maximize the capacity God gives and becomes the basis for building relationships.

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PENERAPAN METODE BERCERITA BAGI KEMAMPUAN NUMERASI SISWA USIA DINI DALAM PEMBELAJARAN TEMATIK [APPLICATION OF THE STORY METHOD FOR EARLY STUDENT NUMERATION ABILITY IN THEMATIC LEARNING]

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ABSTRACT

Based on the results of observations made at a Christian Kindergarten in Tangerang, it was found that there was an unevenness in the numeracy abilities of early-age students. Some students already have the ability to count numbers 1 and 3, but some others do not. Therefore, it is necessary to introduce numeracy skills by the teacher so that students have an even numeracy ability. The purpose of writing this scientific work is to describe the application of the storytelling method to the numeracy skills of early-age students in thematic learning. The research method used is descriptive qualitative research method. Based on the results of the discussion, it was found that the application of the storytelling method was carried out in six stage's that were closely related to the introduction of numeracy skills, namely making preparations before learning, checking readiness and providing motivation to students, actively involving students, telling stories with attention to language, developing, and checking student understanding. Through the application of the six stages of the storytelling method in thematic learning it can help teachers to assess and confirm the level of numeracy abilities of early age students. The next suggestion is to pay attention to various indicators of numeracy skills that have not been studied and to pay attention to the time allocation in teaching so that the effectiveness of the six stages of the storytelling method can be assessed.

Keywords: numeracy, storytelling method, early childhood

ABSTRAK

Berdasarkan hasil observasi yang dilakukan pada salah satu Taman Kanak-kanak Kristen di Tangerang ditemukan ketidakrataan kemampuan numerasi siswa usia dini. Beberapa siswa telah memiliki kemampuan membilang bilangan 1 dan 3 namun beberapa lainnya belum. Oleh sebab itu, diperlukan pengenalan kemampuan numerasi oleh guru agar siswa memiliki kemampuan numerasi yang merata. Tujuan penulisan karya ilmiah ini adalah memaparkan penerapan metode bercerita bagi kemampuan numerasi siswa usia dini dalam pembelajaran tematik. Metode penelitian yang digunakan adalah metode penelitian deskriptif kualitatif. Berdasarkan pemaparan hasil pembahasan ditemukan penerapan metode bercerita dilakukan dalam enam tahapan yang berkaitan erat dengan pengenalan kemampuan numerasi yaitu melakukan persiapan sebelum pembelajaran, mengecek kesiapan dan memberikan motivasi kepada siswa, melibatkan siswa secara aktif, bercerita dengan memperhatikan bahasa, melakukan pengembangan, dan mengecek pemahaman siswa. Melalui penerapan keenam tahapan metode bercerita dalam pembelajaran tematik dapat membantu guru untuk menilai serta mengkonfirmasi tingkatan kemampuan numerasi siswa usia dini. Adapun saran selanjutnya adalah

memperhatikan berbagai indikator kemampuan numerasi yang belum dikaji serta memerhatikan alokasi waktu dalam melakukan pengajaran sehingga keenam tahapan metode bercerita dapat dinilai keefektifannya.

Kata Kunci: numerasi, metode bercerita, tematik, anak usia dini

PENDAHULUAN

Kemampuan dalam menggunakan konsep bilangan dan operasi hitung untuk menyelesaikan masalah yang ditemukan sehari-hari merupakan salah satu kemampuan numerasi (Kemdikbud, 2021). Oleh sebab itu, kemampuan numerasi penting untuk dikembangkan. Menurut Nehru, dengan kemampuan numerasi yang baik, dapat membantu seseorang untuk menguasai kemampuan lainnya (Rohim, Rahmawati, & Ganestri, 2021). Sudarti, (2022) menyatakan bahwa dengan memiliki pemahaman angka, simbol, dan analisis informasi dapat membantu seseorang untuk mengaplikasikannya dalam kehidupan nyata. Dengan demikian, kemampuan numerasi dapat membantu seseorang untuk dapat menyelesaikan permasalahan sehari-hari dan menguasai kemampuan lainnya.

Aspek kemampuan numerasi yang berkaitan erat dengan kemampuan dasar matematika dan harus diperkenalkan sejak usia dini adalah kemampuan berhitung, relasi numerasi, dan operasi aritmatika Jordan, et al., 2009 dalam (Ratnasari, 2020). Hal ini sejalan dengan indikator kemampuan kognitif berpikir simbolik pada pendidikan anak usia dini yang dikemukakan oleh permendikbud 137 tahun 2014 salah satunya yaitu kemampuan mengenal, menyebutkan, dan menggunakan konsep bilangan. Indikator kemampuan numerasi dijelaskan lebih rinci pada aspek konten bilangan yaitu siswa memiliki kemampuan membilang, mengenal lambang bilangan, mengenal penjumlahan 1-10, dan mengenal pengurangan 1-10 (Widyaningrum, 2022). Oleh sebab itu, pengenalan bilangan dalam pendidikan anak usia dini merupakan bagian penting untuk dilakukan.

Fakta yang ditemukan pada salah satu TK Kristen di Tangerang adalah beberapa siswa usia dini telah memiliki kemampuan terkait bilangan dengan cukup baik. Kemampuan siswa terkait numerasi ditunjukkan melalui siswa mampu memahami perintah guru untuk mengambil satu buku. Kegiatan tersebut menunjukkan siswa telah memiliki pemahaman yang baik mengenai bilangan satu. Kemampuan numerasi siswa juga ditunjukkan ketika siswa mampu menyanyikan lagu doa dan barisan yang mengandung hitungan. Contoh lain yang ditemukan adalah beberapa siswa menjawab pertanyaan guru dengan mengangkat tiga jari untuk merepresentasikan tiga gambar burung yang ditunjuk oleh guru. Beberapa siswa juga mampu menjawab pertanyaan yang sama dengan menyebutkan bilangan tiga. Oleh sebab itu, melalui pemaparan fakta yang ditemukan beberapa siswa usia dini di salah satu TK di Tangerang telah memiliki kemampuan numerasi khususnya terkait bilangan satu dan tiga. Meskipun demikian, beberapa siswa lainnya belum memiliki kemampuan serupa.

Melalui kesenjangan antara harapan dan fakta-fakta yang telah dipaparkan, terlihat bahwa beberapa siswa usia dini pada salah satu TK di Tangerang sudah mempunyai kemampuan dalam membilang bilangan 1 dan 3. Penulis tidak dapat melihat ketercapaian

kemampuan numerasi siswa pada indikator yang lainnya karena keterbatasan waktu pengambilan data. Meskipun beberapa siswa usia dini telah memiliki kemampuan membilang bilangan 1 dan 3 tetapi guru tetap melakukan berbagai upaya untuk dapat mengenalkan kemampuan numerasi sehingga seluruh siswa dapat memiliki kemampuan membilang yang merata. Cara yang guru gunakan adalah dengan mengenalkan kemampuan numerasi pada pembelajaran tematik. Cara ini merupakan salah satu strategi yang dikemukakan oleh Kemendikbud untuk mengembangkan kemampuan numerasi (Kemdikbud, 2021). Cara lain yang digunakan guru adalah dengan menggunakan metode pengajaran yang sesuai dengan karakteristik siswa usia dini. Penerapan metode bercerita dapat membantu siswa melatih konsentrasi, mengutarakan pemikiran, kemampuan menerjemahkan gambar cerita, menghubungkan gambar dan imajinasi, mengungkapkan imajinasi, berkomunikasi, dan menambah kosakata (Moeslichatoen, 2004). Selain itu pemilihan metode bercerita juga dapat membantu guru mengenalkan kemampuan numerasi kepada siswa usia dini. Oleh sebab itu, penerapan metode bercerita dapat membantu mengenalkan kemampuan numerasi pada siswa usia dini dalam sebuah pembelajaran tematik. Melalui variabel masalah yang diperoleh, maka rumusan masalah yang akan dibahas dalam penelitian ini adalah bagaimana penerapan metode bercerita bagi kemampuan numerasi siswa usia dini dalam pembelajaran tematik. Adapun tujuan dalam penelitian ini adalah untuk memaparkan penerapan metode bercerita bagi kemampuan numerasi siswa usia dini dalam sebuah pembelajaran tematik.

TINJAUAN LITERATUR

Kemampuan Numerasi Siswa Usia Dini

Salah satu kemampuan yang wajib dikembangkan pada anak usia dini adalah kemampuan numerasi. Kemampuan numerasi adalah pengetahuan dan kompetensi untuk (a) memakai beraneka ragam angka dan lambang yang berhubungan dengan matematika dasar untuk mencari solusi dari masalah praktis dalam kehidupan sehari-hari dan (b) menganalisis keterangan yang dimunculkan dalam berbagai bentuk seperti grafik, tabel, bagan, dan sebagainya (Han, et al., 2017). Secara sederhana, numerasi adalah kemampuan menggunakan konsep matematika dan membaca informasi yang disajikan dalam beraneka macam (Susilawati, et al., 2018). Oleh sebab itu, penting untuk dilakukan pengenalan kemampuan numerasi sejak siswa usia dini. Kemampuan numerasi yang diajarkan pada anak usia dini adalah kemampuan yang berhubungan erat dengan kemampuan dasar matematika yaitu berhitung, relasi numerasi, dan operasi aritmatika Jordan, dkk 2009 dalam (Ratnasari, 2020). Ketiga aspek tersebut dijelaskan lebih lanjut bahwa berhitung merupakan keterampilan seseorang untuk menghitung dan mengidentifikasi jumlah benda; relasi numerasi adalah kemampuan untuk menentukan lebih banyak, lebih sedikit lebih tinggi, atau lebih pendek sebuah benda dari benda yang lainnya; dan operasi aritmatika adalah kemampuan dalam menyelesaikan operasi dasar matematika yaitu penjumlahan dan pengurangan (Perdana & Suswandari, 2021).

Indikator kemampuan numerasi pada jenjang PAUD dalam aspek konten bilangan adalah (1) membilang; (2) mengetahui simbol bilangan; (3) mengetahui penjumlahan 1-10;

dan (4) mengetahui pengurangan 1-10 (Widyaningrum, 2022). Dalam penelitian ini, penulis hanya menggunakan satu dari keempat indikator yang dikemukakan oleh Widyaningrum. Hal ini disebabkan karena topik pembelajaran siswa usia dini pada saat melakukan penelitian adalah bilangan. Satu indikator yang digunakan adalah mengenal bilangan. Pengertian membilang menurut Tim Penyusun Kamus Pusat Bahasa (2003), adalah kecakapan mengetahui jumlah banyaknya suatu benda yang dilakukan dengan cara menghitung dan menyebutkan satu persatu. Kemampuan membilang adalah kemampuan siswa memahami, mengetahui, dan menyebutkan bilangan (Haryuni, 2013). Sejalan dengan pendapat tersebut menurut Nari, Akmay, & Sasmita (2019), kemampuan membilang adalah kecakapan siswa untuk membilang bilangan tanpa harus mengenal simbol bilangannya. Membilang adalah kemampuan untuk berhitung dengan membilang bilangan asli mulai dari bilangan satu dengan menunjuk pada benda yang ingin dihitung (Shamsudin, 2002). Dengan demikian dapat diartikan bahwa kemampuan membilang adalah kecakapan atau kemampuan siswa untuk menghitung banyaknya suatu benda dengan menyebutkan bilangan asli dan menunjuk pada benda tersebut satu persatu hingga seluruh benda terhitung.

Pendidikan usia dini adalah pendidikan yang diperuntukkan bagi anak usia 0-6 tahun untuk mempersiapkan mereka memasuki jenjang pendidikan yang lebih tinggi. Salah satu bagian yang mulai dikembangkan adalah kemampuan numerasi yang tergolong dalam aspek kognitif. Kemampuan numerasi adalah kecakapan seseorang untuk menggunakan berbagai konsep matematika dasar untuk menyelesaikan berbagai permasalahan sehari-hari. Selain itu dengan kemampuan numerasi yang baik dapat membantu seseorang untuk membaca informasi yang ditampilkan dalam berbagai bentuk untuk menarik kesimpulan serta mengambil keputusan. Secara khusus bagi siswa, kemampuan numerasi tidak hanya digunakan untuk membantu menyelesaikan berbagai permasalahan sehari-hari, tetapi dengan kemampuan numerasi yang baik dapat membantu mereka untuk menguasai berbagai pelajaran lainnya. Pada jenjang pendidikan usia dini, tahapan kemampuan numerasi yang harus dimiliki yaitu mampu memahami konsep bilangan, lambang bilangan, relasi numerasi seperti lebih banyak atau lebih sedikit, mengklasifikasi benda berdasarkan ciri-ciri tertentu, serta dapat melakukan operasi hitung penjumlahan dan pengurangan dengan memakai benda-benda konkrit.

Metode Bercerita dalam Pembelajaran Tematik

Kegiatan menyampaikan informasi, pesan, atau dongeng yang dilakukan secara lisan kepada orang lain dengan menggunakan alat atau tanpa alat dengan tujuan untuk memberikan rasa menyenangkan disebut sebagai bercerita (Saribu & Hidayah, 2019). Izzati dan Yulsyofriend (2020) menambahkan metode bercerita juga berkaitan dengan adanya penyaluran ilmu, mengasah informasi, dan pemberian pengetahuan baru kepada anak-anak namun cerita yang dibawakan harus dapat berkaitan dengan tujuan pembelajaran serta dapat mengundang perhatian atau menarik minat siswa. Hal ini sesuai dengan karakteristik metode bercerita yaitu topik dan tema cerita yang disesuaikan dengan minat anak; gambar atau ilustrasi yang digunakan sesuai dengan kondisi sehari-hari anak di rumah dan sekolah;

membantu mengembangkan salah satu aspek perkembangan anak yaitu aspek kognitif khususnya berhitung (Pratiwi, Wirya, & Asril, 2015).

Bentuk metode bercerita dibagi menjadi dua yaitu bercerita tanpa menggunakan alat peraga dan bercerita dengan menggunakan alat peraga. Penerapan metode bercerita tanpa menggunakan alat peraga adalah kegiatan bercerita yang guru lakukan tanpa memakai alat peraga sehingga guru berfokus untuk menggunakan mimik, vokal, tempo, gaya bahasa, dan intonasi sedangkan dalam penerapan metode bercerita memakai alat peraga adalah guru menyediakan alat peraga yang akan digunakan dalam cerita (Katoningsih, 2021). Dalam penerapan metode bercerita menggunakan alat peraga terbagi menjadi dua yaitu menggunakan alat peraga langsung dan alat peraga tidak langsung. Pertama, tahapan penerapan metode bercerita dengan alat peraga langsung adalah (1) menyiapkan alat peraga; (2) mengajak anak fokus pada penjelasan guru; (3) memberikan anak motivasi untuk mendengarkan guru; (4) memberikan anak kesempatan untuk memberikan judul cerita; guru menyebutkan judul cerita; (5) guru bercerita dengan memegang alat peraga; dan (6) anak membuat kesimpulan diakhir cerita. Kedua, tahapan penerapan metode bercerita dengan alat peraga tidak langsung yaitu (1) guru menyampaikan tema dan tujuan cerita; (2) guru mengatur posisi duduk anak; (3) guru membuka cerita; (4) guru melakukan pengembangan cerita; (5) guru menceritakan dengan memperhatikan bahasa yang digunakan; (6) guru menutup cerita dengan memberikan pertanyaan; dan (7) guru membuat penilaian (Katoningsih, 2021).

Penerapan metode bercerita memberikan berbagai manfaat kepada anak usia dini. Melalui penerapan metode bercerita dapat menolong anak usia dini untuk melatih kemampuan berpikir, berkonsentrasi, berimajinasi; berbahasa, serta berkomunikasi (Manurung & Simatupang, 2019). Manfaat penerapan metode bercerita juga ditambahkan bahwa dapat membantu pengembangan kognitif anak usia dini melalui penyampaian informasi dengan cara yang menyenangkan serta melatih anak usia dini untuk berpikir kritis, logis, dan mengembangkan imajinasi dan fantasi anak (Izzati & Yulsyofriend, 2020).

Oleh sebab itu, dapat disimpulkan bahwa metode bercerita adalah salah satu metode pembelajaran yang dilakukan guru untuk mengembangkan kemampuan anak usia dini dengan menggunakan atau tidak menggunakan alat peraga. Pengembangan kemampuan dengan metode ini harus memperhatikan beberapa hal penting seperti tema, topik, ilustrasi, serta alat peraga yang digunakan agar sesuai dengan perkembangan dan minat anak usia dini. Tahapan penerapan metode yang pertama adalah guru melakukan persiapan seperti memilih topik, tema, serta media yang akan digunakan. Kedua, guru memberikan motivasi kepada siswa serta memastikan kesiapan siswa sebelum melakukan pembelajaran. Ketiga, guru melibatkan siswa secara aktif dalam pembelajaran dengan cara meminta siswa untuk menentukan judul cerita atau memberikan siswa pertanyaan-pertanyaan di tengah pembelajaran. Keempat, guru bercerita dengan memerhatikan kata-kata, kalimat, serta alat peraga yang digunakan. Kelima, guru melakukan pengembangan. Serta keenam adalah guru memeriksa pemahaman siswa dengan memberikan pertanyaan atau meminta siswa menceritakan kembali. Tahapan metode yang telah dipaparkan ini merupakan tahapan

penerapan metode bercerita yang diterapkan penulis dalam penelitian. Penerapan metode bercerita ini tidak hanya dilakukan agar siswa memiliki banyak kosakata tetapi juga mengembangkan kognitif siswa seperti berhitung.

Penerapan Metode Bercerita terhadap Kemampuan Numerasi Siswa Usia Dini dalam sebuah Pembelajaran Tematik

Masalah terkait kemampuan numerasi dapat diselesaikan dengan pengenalan numerasi yang dilakukan berulang-ulang serta dalam berbagai konteks. Selain itu pengenalan numerasi harus dapat dilakukan dengan metode yang sesuai dan tepat dengan karakteristik anak usia dini. Oleh karena itu, anak usia dini memerlukan penerapan numerasi dalam berbagai mata pelajaran lainnya seperti tematik serta metode yang dapat mendukungnya. Penerapan atau pengintegrasian kemampuan numerasi dalam pembelajaran tematik dapat membantu anak usia dini untuk menerapkannya dalam berbagai konteks permasalahan sehari-hari. Pengintegrasian kemampuan numerasi dalam pembelajaran lintas kurikulum dapat membantu siswa untuk mengerti serta memahami cara mengaplikasikannya dalam menyelesaikan masalah-masalah sehari (Perdana & Suswandari, 2021). Selain mengintegrasikan kemampuan numerasi dengan pembelajaran lintas kurikulum, guru juga perlu memperhatikan metode pembelajaran yang dipakai. Metode pembelajaran yang digunakan seharusnya sesuai dengan perkembangan anak usia dini serta dapat menolong guru untuk mengembangkan kemampuan numerasinya. Salah satu metode pembelajaran yang dipakai oleh guru untuk mengajar pembelajaran tematik serta mengenalkan kemampuan numerasi adalah metode bercerita.

Dampak pengintegrasian kemampuan numerasi dalam pembelajaran tematik dinilai berhasil pada beberapa penelitian berikut. Melalui penelitian yang dilakukan di SD Muhammadiyah 1 Kota Malang dinilai berhasil meskipun belum mencapai keseluruhan indikator kemampuan numerasi (Ekowati, Astuti, Utami, Mukhlishina, & Suwandayani, 2019). Salah satu contoh usaha yang digunakan sekolah adalah dengan melaksanakan pembelajaran non matematika yang melibatkan unsur numerasi. Selain itu wawancara yang dilakukan pada salah satu siswa kelas 5B SD Negeri 101880 Aek Godang menyatakan bahwa proses pembelajaran numerasi pada tahap dua yaitu ketika guru mengaitkan materi pembelajaran dengan numerasi serta melakukan latihan memecahkan soal masalah sehari-hari yang berkaitan dengan numerasi dapat membantu siswa untuk lebih menguasainya meskipun dalam penerapannya perlu dilakukan beberapa peningkatan (Siregar, 2022). Mengintegrasikan kemampuan numerasi dengan pembelajaran tematik juga dinilai memberikan pengaruh terhadap perkembangan siswa kelas 2 SD pada salah satu kelompok belajar. Perkembangan kemampuan numerasi siswa kelas 2 adalah siswa mampu mengenal lebih dalam mengenai operasi dasar aritmatika yaitu penjumlahan, pengurangan, dan perkalian hingga mereka dapat menyelesaikan berbagai soal yang memerlukan operasi aritmatika untuk menyelesaikannya (Munadi & Rahayu, 2022).

Selain itu, penggunaan metode dalam pembelajaran juga dapat mempengaruhi penerapan kemampuan numerasi pada kelas anak usia dini. Beberapa penelitian yang

menunjukkan keberhasilan penerapan metode bercerita terhadap penanaman konsep matematika sebagai tahap awal pengenalan kemampuan numerasi adalah sebagai berikut. Penerapan metode bercerita pada salah satu sekolah untuk pengenalan konsep waktu anak tunagrahita ringan dinilai berhasil. Hal ini ditunjukkan melalui kesimpulan penelitian yang menunjukkan bahwa adanya pengaruh dari penerapan metode bercerita dengan menggunakan media gambar berseri bagi anak tunagrahita ringan terhadap kemampuan pengenalan konsep waktu (Diningtias, 2019). Selain itu penelitian yang dilakukan Cahaya dan Poerwati, (2017) menunjukkan bahwa kemampuan matematika dapat ditingkatkan dengan menerapkan metode mendongeng. Hal ini ditunjukkan melalui ketuntasan hasil belajar pada kemampuan matematika anak pada pengamatan awal 51,85% meningkat pada siklus I menjadi 66,67% dan siklus II 81,48%. Faktor pendukung dalam penerapan metode mendongeng untuk meningkatkan kemampuan matematika anak Kelompok B TK Widya Puspita Canggu adalah (1) Menarik perhatian, antusias, dan partisipasi anak ketika guru menerapkan metode mendongeng dengan menggunakan berbagai media; (2) Kemampuan guru untuk mendongeng dan mengaitkannya dengan kemampuan matematika; (3) Rasa ingin tahu anak; dan (4) Kerjasama yang dijalin antara peneliti, guru, dan kepala sekolah.

PENDEKATAN PEMECAHAN MASALAH

Pendekatan pemecahan masalah yang digunakan dalam penelitian ini adalah deskriptif kualitatif. Pendekatan deskriptif adalah penelitian yang dilakukan dengan mendeskripsikan suatu fenomena, peristiwa, atau kejadian yang terjadi sekarang yang digambarkan seperti yang terjadi pada lapangan (Sudjana, 2009). Pendekatan deskriptif kualitatif adalah analisis induktif yang bertujuan pada pencarian, penemuan, dan logika induktif untuk mendapati teori yang berasal pada pola dan realita yang terjadi (Nugrahani, 2014). Dengan demikian, penelitian deskriptif kualitatif adalah penelitian yang dilakungan dengan memotret suatu kejadian atau peristiwa untuk dapat diteliti lebih dalam. Penelitian dilakukan dalam rentang waktu 5 minggu dari bulan Juli hingga Agustus 2022 dengan melibatkan siswa dari salah satu TK di Tangerang, di mana subjek penelitian memiliki rentang usia 3-4 tahun. Peneliti menggunakan alat peraga yang telah divalidasi oleh guru pamong dan juga rekan sejawat, guna mendapatkan gambaran terkait kemampuan numerasi siswa TK tersebut. Instrumen lain yang digunakan adalah lembar observasi untuk melihat gambaran awal serta RPP dan jurnal refleksi guna mendokumentasi setiap tahapan yang dilakukan. Teknik analisis data yang digunakan dalam penelitian ini adalah menggunakan narasi deskriptif dengan menganalisis tiap tahapan dari metode bercerita terhadap indikator dari kemampuan numerasi siswa usia dini.

PEMBAHASAN

Kemampuan numerasi merupakan kemampuan yang perlu untuk dikembangkan sejak usia dini. Kemampuan ini tidak hanya berbicara mengenai konsep matematika tetapi menerapkan konsep tersebut dalam kehidupan sehari-hari. Menurut KEMDIKBUD Indikator

kemampuan numerasi pada jenjang pendidikan anak usia dini adalah menghitung menggunakan simbol bilangan dan menyesuaikan bilangan dengan simbol bilangan. Namun pada penelitian ini, indikator kemampuan numerasi yang dipakai adalah kemampuan membilang pada aspek indikator kemampuan numerasi yang dikemukakan oleh (Widyaningrum, 2022). Hal ini dilakukan karena materi yang sedang diajarkan pada siswa usia dini di salah satu TK di Tangerang adalah mengenal bilangan.

Fakta yang ditemukan adalah para siswa usia dini pada salah satu TK di Tangerang belum mampu mencapai indikator kemampuan numerasi seperti yang telah dipaparkan. Melalui hasil observasi, ditemukan bahwa siswa kelas K1 dengan rentang usia 3-4 tahun mampu memahami konsep bilangan satu. Hal ini ditunjukkan dengan kemampuan siswa memahami perintah guru bahwa setiap siswa harus mengambil satu buku untuk dibaca. Kemampuan numerasi siswa juga ditunjukkan ketika siswa mampu menyanyikan lagu doa dan barisan yang mengandung hitungan. Meskipun demikian beberapa siswa pada kelas tersebut masih sulit untuk memahami konsep bilangan tiga. Hal ini ditunjukkan melalui beberapa siswa belum mampu merepresentasikan tiga jari untuk tiga gambar burung yang ditunjuk oleh guru. Pada saat yang sama, beberapa siswa juga belum mampu menjawab jumlah burung yang ada pada gambar yang ditunjukkan guru. Melalui pemaparan hasil observasi, kesimpulan kemampuan numerasi siswa usia dini pada salah satu TK di Tangerang adalah beberapa anak telah memiliki pemahaman konsep yang baik mengenai bilangan satu dan tiga sedangkan beberapa siswa lainnya belum.

Berdasarkan penjelasan fakta-fakta kemampuan numerasi siswa yang telah dipaparkan, faktor yang mempengaruhi beberapa siswa telah memiliki kemampuan numerasi lebih dibandingkan siswa lainnya adalah karena telah menerima pengajaran tersebut sebelumnya. Bagi beberapa orang tua kemampuan numerasi adalah kemampuan yang harus dikembangkan sejak usia dini sehingga mereka cenderung untuk memberikan les tambahan kepada anaknya (Kurniasih & Watini, 2022). Sedangkan bagi siswa lainnya yang belum memiliki kemampuan yang sama, karena mereka belum menerima pembelajaran tersebut. Oleh sebab itu, untuk menyelesaikan permasalahan yang telah dipaparkan adalah perlunya pengenalan kemampuan numerasi khususnya kemampuan membilang bagi siswa usia dini kelas K1 pada kisaran 3-4 tahun.

Usaha yang dilakukan penulis untuk mengatasi permasalahan yang ada adalah dengan menerapkan metode bercerita terhadap kemampuan numerasi dalam sebuah pembelajaran tematik. Hal inilah yang menjadi keunikan dalam penelitian ini bahwa penerapan metode bercerita tidak hanya digunakan untuk mengembangkan kemampuan berbahasa dan berkomunikasi anak, namun dapat digunakan terhadap kemampuan numerasi siswa. Usaha pertama yang dilakukan guru adalah memperkenalkan kepada siswa mengenai membilang yang merupakan kemampuan awal untuk memiliki pemahaman konsep bilangan pada berbagai mata pelajaran. Seperti guru menjelaskan instruksi dengan menggunakan kalimat yang mengandung bilangan yaitu (1) “Ambil satu buku untuk satu orang”, (2) “Ini adalah seekor kodok/ satu kodok” dengan menunjukkan gambar seekor kodok, dan (3) “Ini kedua kalinya kita mendengarkan cerita baby owl”. Upaya ini sejalan dengan pandangan yang

dikemukakan oleh Dewayani, et al., (2021) bahwa kemampuan numerasi dapat dikembangkan melalui mata pelajaran tematik. Upaya kedua yang dilakukan guru adalah dengan memilih metode bercerita. Metode bercerita dipilih oleh guru karena disesuaikan dengan karakteristik siswa usia dini. Kemdikbud, (2021) menyatakan bahwa salah satu metode yang mampu mendukung munculnya kemampuan numerasi dalam pembelajaran adalah bercerita.

Tahapan penerapan metode bercerita bagi kemampuan numerasi siswa usia dini dalam pembelajaran tematik dijelaskan lebih lanjut dengan menggunakan enam tahapan metode bercerita yang telah dijelaskan sebelumnya. Tahapan pertama, penulis mempersiapkan rancangan pembelajaran yang mencakup pemilihan topik, tema, dan media pembelajaran. Tahapan ini dilakukan oleh penulis untuk dapat mempersiapkan pembelajaran yang sesuai dengan tingkatan kelas, karakteristik, dan minat siswa sehingga menghindari penerapan metode konvensional yang dapat membuat siswa bosan mengikuti pembelajaran. Topik pembelajaran yang dipilih oleh penulis adalah pengenalan konsep bilangan 1, sedangkan tema pembelajaran disesuaikan dengan rancangan pembelajaran tahunan yang telah ditetapkan sekolah. Selain itu, media pembelajaran yang digunakan guru adalah PPT interaktif dan benda-benda yang tersedia di sekitar siswa. Media pembelajaran PPT dan benda-benda yang tersedia di sekitar siswa dinilai tepat untuk mengembangkan kemampuan numerasi siswa dengan menggunakan metode bercerita oleh penelitian yang dilakukan oleh Savitri, (2018) dan Nuraini, (2014). Pemilihan topik, tema, dan media pembelajaran juga dinilai positif melalui *feedback* guru mentor.

Tahapan kedua, guru mengecek kesiapan siswa dengan melihat kehadiran siswa dalam kelas daring dan menanyakan kabar siswa. Pada tahap ini, guru juga memberikan semangat kepada siswa. Bentuk motivasi belajar yang diberikan guru adalah dengan menjelaskan berbagai aktivitas yang akan dilakukan yaitu bercerita dan bermain. Pada penjelasan tahapan pembelajaran yang akan dilakukan guru kalimat-kalimat yang mengandung bilangan. Contoh kalimat yang guru gunakan adalah “Pertama, kita harus menemukan tas”. Guru juga menjelaskan bahwa melalui pembelajaran hari ini dapat membantu siswa menjadi anak mandiri dengan latihan menyiapkan tas sekolah sendiri melalui aktivitas yang akan dilakukan. Pemberian motivasi tersebut dinilai berhasil dengan melihat respon siswa yang aktif dan menikmati kegiatan yang disusun oleh guru.

Tahapan ketiga adalah guru mengajak siswa terlibat aktif dalam pembelajaran dengan memberikan berbagai pertanyaan. Kesempatan yang diberikan guru untuk mengajak siswa terlibat aktif dalam pembelajaran antara lain menjawab pertanyaan yang diberikan guru. Pertanyaan yang diberikan guru terbagi dalam tiga aktivitas. (1) pertanyaan yang diberikan di awal kelas yaitu *mereview* pembelajaran sebelumnya. Bentuk pertanyaan yang diberikan guru adalah siapa yang mengingat nama tokoh yang ada dalam cerita sebelumnya. (2) pertanyaan diberikan pada saat penyampaian materi, ketika sedang bercerita atau melakukan aktivitas. Bentuk pertanyaan yang diberikan guru adalah dapatkah siswa menunjukkan satu barang yang akan dibawa Andy ke sekolah pada gambar yang diperlihatkan dan guru meminta siswa mengambil jenis dan jumlah barang sesuai dengan instruksi guru berdasarkan cerita yang

dibawakan. Ketika guru memberikan pertanyaan tersebut, terlihat respon dari siswa yang menunjukkan barang yang dibawa sesuai dengan jumlah yang diinstruksikan guru dan beberapa siswa lainnya yang belum. (3) pertanyaan diberikan pada saat guru mengecek pemahaman siswa. Bentuk pertanyaan yang diberikan guru adalah kesimpulan pembelajaran dan guru meminta siswa menghitung jumlah pulpen yang dimiliki oleh guru. Pertanyaan yang diberikan guru tersebut mendapat respon oleh siswa yang dapat langsung menjawab pertanyaan guru dengan tepat namun beberapa yang lainnya dapat menjawab dengan tepat ketika telah berhitung bersama guru. Melalui pemaparan berbagai aktivitas yang dilakukan maka dapat disimpulkan bahwa pada tahap ini guru memiliki kesempatan untuk mengenalkan dan mengecek kemampuan numerasi anak usia dini pada aspek menghitung objek nyata melalui berbagai pertanyaan yang diberikan.

Tahap empat, guru bercerita dengan menggunakan bahasa, kata, dan kalimat yang sesuai dengan tingkatan anak umur usia dini sehingga penyampaian materi dapat berjalan dengan baik. Selain itu, guru juga memerhatikan alat peraga yang digunakan yaitu PPT interaktif dan benda-benda yang dapat diperoleh dengan mudah seperti tas sekolah, pensil, buku, penghapus, botol minum. Penggunaan alat peraga berupa benda-benda yang bisa ditemukan di sekitar siswa dapat memberikan dampak positif yang dapat dilihat dari respon siswa seperti menikmati kegiatan mengambil barang.

Tahap lima dilakukan penulis dengan mengajak siswa usia dini terlibat aktif dalam pembelajaran. Keterlibatan siswa dalam pembelajaran tidak hanya menjawab pertanyaan tetapi penulis melakukan pengembangan dengan melibatkan siswa untuk berperan dalam cerita yang dibawakan. Peranan siswa dalam cerita dilakukan dengan menjalankan misi yaitu membantu tokoh utama menyiapkan tas sekolah untuk hari pertama ke sekolah. Pengembangan yang dilakukan guru dinilai positif melalui komentar mentor yang menyatakan siswa menikmati proses pembelajaran melalui aktivitas dan perintah yang diberikan guru**.** Pada pengembangan aktivitas yang dilakukan dengan mengambil barang sesuai jenis dan jumlah yang diinstruksikan dapat membantu siswa semakin mengenal konsep bilangan atau khususnya pada indikator kemampuan numerasi yaitu membilang.

Tahap keenam dilakukan guru dengan mengecek pemahaman siswa dengan cara menjawab pertanyaan guru. Bentuk pertanyaan yang dapat diberikan guru adalah kesimpulan pembelajaran dan guru meminta siswa menghitung jumlah pulpen yang dimiliki oleh guru. Pada tahapan ini, guru dapat mengaitkannya dengan mengecek tingkatan kemampuan numerasi siswa khususnya pada indikator nomor 1 yaitu menghitung objek nyata. Meskipun demikian, pada kenyataannya penulis belum menerapkan tahapan keenam karena keterbatasan waktu yang dimiliki.

Berdasarkan penerapan keenam tahapan metode bercerita dalam pembelajaran tematik, maka guru dapat menilai atau mengkonfirmasi kemampuan numerasi siswa usia dini. Hal ini dapat dilihat melalui penerapan keenam tahapan yang dapat memunculkan kemampuan numerasi siswa. Sebagai contoh adalah ketika guru memberikan pertanyaan atau memberikan instruksi yang mengandung numerasi maka dapat membantu guru untuk menilai tingkatan kemampuan numerasi siswa khususnya pada indikator membilang.

Anak usia dini merupakan ciptaan Allah yang dijadikan seturut gambar dan rupa Allah. Anak usia dini merupakan pribadi yang Allah ciptakan menurut gambar dan rupanya dengan memiliki keunikan dan talenta masing-masing (Van Brummelen, 2008). Talenta yang dimiliki setiap anak harus dapat dikembangkan untuk memuliakan Tuhan. Pada awal penciptaan, Tuhan menciptakan manusia sebagai makhluk yang baik namun karena kejatuhan ke dalam dosa maka manusia berada pada kondisi rusak dan dosa telah meracuni setiap kemampuan manusia sehingga ia tidak dapat memuliakan Allah dengan kemampuan yang dianugerahkan kepadanya (Erickson, 2003). Oleh sebab itu siswa perlu untuk diperkenalkan dengan Kristus sebagai satu-satunya Juruselamat yang dapat menyelamatkan mereka dari dosa (Knight, 2009). Pada bagian inilah diperlukan guru Kristen yang tidak hanya melakukan tugasnya untuk mengajar tetapi juga menjadi rekan sekerja Allah untuk membawa siswa mengenal Kristus (Priyatna, 2017).

KESIMPULAN DAN SARAN

Penerapan metode bercerita terhadap kemampuan numerasi siswa usia dini dalam sebuah pembelajaran tematik dapat dilakukan melalui enam tahapan. Secara garis besar, keenam tahapan tersebut meliputi: (1) ketepatan topik dan media pembelajaran, (2) pemberian motivasi siswa, (3) penentuan pertanyaan untuk menstimulus keterlibatan siswa, (4) pemberian cerita yang dilakukan guru dengan mempertimbangkan bahasa serta alat peraga, (5) merancang aktivitas agar siswa terlibat dalam cerita, dan (6) mengecek pemahaman siswa. Pertanyaan yang diberikan oleh guru dapat bermuatan numerasi. Oleh sebab itu, melalui penerapan metode bercerita dalam pembelajaran tematik dapat membantu guru untuk menilai atau mengkonfirmasi kemampuan numerasi siswa usia dini melalui setiap tahapan pembelajaran yang telah dipaparkan.

Pada saat melakukan penelitian ini, penulis berefleksi bahwa penting bagi guru memandang siswa sebagai gambar dan rupa Allah. Dengan memandang siswa sebagai gambar dan rupa Allah dapat membantu guru untuk melihat siswa sebagai pribadi yang dianugerahkan kemampuan oleh Allah serta memiliki keunikan masing-masing. Keunikan yang dianugerahkan Allah dapat dikembangkan melalui proses pembelajaran di dalam kelas yang disesuaikan dengan berbagai keunikan siswa. Sebagai saran bagi keberlanjutan penelitian ini adalah perlunya memperhatikan perancangan aktivitas yang mampu mengulas indikator kemampuan numerasi agar semuanya dapat terkaji dengan maksimal serta memerhatikan alokasi waktu dalam melakukan pengajaran sehingga keenam tahapan metode bercerita dapat dilihat efektivitasnya.

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ANALISIS BERPIKIR KRITIS MATEMATIS SISWA DALAM MENYELESAIKAN MASALAH KONTROVERSIAL [THE ANALYSIS OF STUDENTS' MATHEMATICAL CRITICAL THINKING FOR SOLVING CONTROVERSIAL ISSUES]

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ABSTRACT

This research is a descriptive study using a qualitative approach with the aim of analyzing students' critical thinking skills in solving controversial mathematics problems using six indicators of IDEALS critical thinking. The research subjects in this study were 3 students of class X MIPA 1 SMA N 1 Singaraja who were obtained through a purposive sampling method. The research instruments this time were researchers, student worksheets, student test results, and interview results. Miles and Huberman's model is used in analyzing research data, through the process of data reduction, data presentation, and ending with drawing conclusions based on the data obtained. The results of the research and interviews show that students' critical thinking skills solve controversial mathematics problems with six indicators of IDEALS critical thinking, namely: (1) identify, it is found that the three subjects are able to identify the main problem and identify solutions to problems given that do not make sense, (2) define, it was found that the three subjects could define what was known and what was asked in the mathematical problem, but only by re-copying the questions, (3) enumerate, it was found that the three subjects only found one problem solving strategy that made sense, (4) analyze , each of the three subjects only used one problem-solving strategy for analysis, (5) list, it was found that the three subjects were able to state reasons for using the problem-solving strategy they used respectively, and (6) self-correct, it was obtained that the three subjects have re-checked the delivery strategy problem solutions that they use.

Keywords: critical thinking skills, mathematics controversial problem

ABSTRAK

Penelitian ini merupakan penelitian deskriptif menggunakan pendekatan kualitatif dengan tujuan menganalisis kemampuan berpikir kritis siswa dalam menyelesaikan masalah kontroversial matematika menggunakan enam indikator berpikir kritis IDEALS. Subjek penelitian dalam penelitian ini yaitu 3 orang siswa kelas X MIPA 1 SMA N 1 Singaraja yang didapatkan melalui metode *purposive sampling*. Dengan instrumen penelitian kali ini yaitu peneliti, lembar kerja siswa, hasil tes siswa, dan hasil wawancara. Model Miles dan Huberman digunakan dalam menganalisis data penelitian, melalui proses reduksi data, penyajian data, serta diakhiri dengan penarikan kesimpulan berdasarkan data yang diperoleh. Adapun hasil penelitian serta wawancara menunjukkan bahwa kemampuan berpikir kritis siswa menyelesaikan masalah kontroversial matematika dengan enam indikator berpikir kritis IDEALS, yaitu: (1) *identify*, diperoleh bahwa ketiga subjek mampu mengidentifikasi pokok

permasalahan dan mengidentifikasi solusi dari masalah yang diberikan tidak masuk akal, (2) *define*, diperoleh bahwa ketiga subjek dapat mendefinisikan terkait yang diketahui serta apa yang ditanyakan pada persoalan matematika, tetapi hanya dengan menyalin ulang soal, (3) *enumerate*, diperoleh bahwa ketiga subjek hanya menemukan satu strategi penyelesaian masalah yang masuk akal, (4) *analyze*, masing-masing dari ketiga subjek hanya menggunakan satu strategi penyelesaian masalah tersebut untuk dianalisis, (5) *list*, diperoleh bahwa ketiga subjek mampu menyebutkan alasan menggunakan strategi penyelesaian masalah yang mereka gunakan masing-masing, dan (6) *self-correct*, diperoleh bahwa ketiga subjek sudah mengecek kembali strategi penyelesaian masalah yang masing-masing mereka gunakan.

Kata Kunci: kemampuan berpikir kritis, masalah kontroversial matematika

PENDAHULUAN

Kemampuan berpikir tingkat tinggi yang meliputi berpikir logis, reflektif, metakognisi, kritis, serta berpikir kreatif menjadi tolak ukur dalam tercapainya suatu pembelajaran matematika (Rahayuningsih & Kristiawan, 2018), dimana kemampuan berpikir tingkat tinggi ini datang melalui proses belajar atau pendidikan yang mengkhusus pada Pendidikan matematika (Abdullah, 2013). Matematika dikatakan sebagai ilmu yang erat digunakan dalam memenuhi kebutuhan di berbagai bidang, baik itu bidang ekonomi, ilmu pengetahuan, teknologi, industri, dan lainnya (Tanjung, 2019). Penggunaan ilmu matematika ditekankan kembali oleh Carl Friedrich Gauss yang menyebutkan "*mathematics is the queen of sciences*" (Maswar, 2019). Penggunaan ilmu matematika tersebut mendasari siswa untuk memiliki kemampuan dalam berpikir kritis, kreatif, komunikatif, serta kolaboratif sebagai pemenuhan keterampilan di abad ke-21 (Abidin dan Tohir 2019).

Krulik dan Rudnick (Mahmuzah, 2015) menyebutkan keterampilan berpikir telah diklasifikasikan menjadi 4 tingkat, yaitu menghafal (*recall thinking*), dasar (*basic thinking*), kritis (*critical thinking*), dan kreatif (*creative thinking*). Dalam kurikulum 2013 juga menyebutkan bahwa satu capaian yang harus dicapai dalam suatu proses belajar adalah mencetak generasi yang mampu dalam berpikir kritis (Pertiwi, 2018). Bahkan hasil penelitian dari Syafitri dkk (2021) menyatakan kemampuan berpikir kritis pada siswa berpotensi baik dalam membangun kualitas berpikir, misalnya ketika dihadapkan dalam situasi genting mereka mampu mengambil keputusan dengan tepat, cepat dan efisien sehingga berdampak sangat penting pada kehidupan sehari-hari. Lebih lanjut, penelitian Kurniawati (2020) menyebutkan bahwa dengan keterampilan berpikir kritis mampu meminimalkan kesalahan ketika menghadapi suatu masalah dan menghasilkan penyelesaian diikuti kesimpulan yang tepat.

Penelitian yang dilakukan Belecina & Ocampo (2018) dengan subjek penelitian mahasiswa menghasilkan bahwa pemikiran kritis mahasiswa meningkat dengan signifikan setelah dihadapkan dengan situasi masalah. Lebih lanjut, penelitian Nugroho dkk. (2018) terkait berpikir kritis dengan subjek penelitian para calon guru menyebutkan bahwa kemampuan berpikir kritis muncul ketika dihadapkan dengan permasalahan yang di dalamnya terdapat konflik kognitif serta hasil yang saling bertentangan. Permasalahan kognitif ini

terjadi ketika siswa diberikan suatu permasalahan kontroversial (Rosyadi, 2021). Kontroversi dalam matematika sendiri muncul ketika menjumpai permasalahan yang berbeda dari permasalahan biasanya, sehingga menimbulkan adanya perbedaan pendapat (Rosyadi, 2021). Dijelaskan pula dalam menghadapi permasalahan kontroversi, diperlukan sebuah argumen yang logis terkait permasalahan yang dihadapi. Hal tersebut karena ketika dihadapkan dengan permasalah kontroversial, seorang individu membutuhkan argumen yang logis dalam penyelesaiannya (Rosyadi, 2021). Hasil penelitian Susanto dkk. (2020) juga menyatakan bahwa keterampilan berpikir kritis mampu ditingkatkan dengan menerapkan proses pembelajaran berbantuan *controversial issue*

Argumentasi diperlukan dalam penggabungan tahapan berpikir siswa diiringi dengan pengecekan kembali ketika siswa menyampaikan pendapat dalam menyelesaikan masalah kontroversial (Rosyadi, 2021). Kemudian, penelitian dari Rosyadi dkk., (2021) menyatakan pada proses *identifying* dan *connecting* berlangsung fase analisis yang dilakukan oleh guru terhadap proses berpikir kritis siswa dalam menyelesaikan permasalahan kontroversial matematika dengan berbantuan *high order thinking skills,* dilanjutkan proses *applying* yang digunakan guru dalam mengevaluasi, terakhir proses *argumentation* dan *clarifying* yang digunakan dalam mencipta. Namun, diketahui bahwa penelitian Rosyadi (2021) menggunakan subjek penelitian mahasiswa dan penelitian dari Rosyadi dkk. (2021) menggunakan subjek penelitian calon guru. Guru ditempatkan sebagai pengajar dan siswa sebagai subjek belajar dalam suatu kegiatan belajar mengajar. Dari posisi inilah, peran siswa dalam proses pembelajaran diharapkan setara dengan guru. Dalam hal ini, siswa diminta aktif dalam proses pembelajaran. (Hadi Kusmanto) Dalam proses belajar-mengajar di kelas banyak guru yang menghambat peluang kekritisan siswanya. Dalam mengerjakan suatu permasalahan kontroversial, siswa cenderung menjawab dengan langkah yang keliru. Sehingga sulit untuk dalam proses penalaran matematis. Dengan demikian, penelitian tentang menyelesaikan masalah kontroversial matematika yang memiliki kaitan dengan indikator dalam berpikir kritis belum ada yang menggunakan subjek penelitian siswa. Penelitian dari Chowning (Mueller & Yankelewitz, 2014) menyebutkan bahwa penelitian antara hubungan permasalahan kontroversial dan berpikir kritis masih membutuhkan penelitian lebih lanjut.

Mengingat betapa pentingnya berpikir kritis pada pembelajaran matematika khususnya dalam menyelesaikan permasalahan kontroversial, maka hal ini perlu dikaji lebih komprehensif lagi. Dengan berbagai permasalahan tersebut, peneliti memiliki tujuan guna mengetahui bagaimana proses berpikir kritis siswa dalam menyelesaikan masalah kontroversial.

TINJAUAN LITERATUR

Masalah Matematika Kontroversial

Masalah kontroversial menyebabkan terjadinya perbedaan pendapat antar siswa sebagai akibat dari adanya suatu konflik kognitif (Mueller & Yankelewitz 2014). Masalah kontroversial didasari dengan suatu isu kontroversial yakni suatu hal yang mudah diterima,

tetapi mudah juga untuk ditolak oleh seseorang atau kelompok lain (Komalasari, 2010). Kecenderungan dalam memihak didasari dengan pertimbangan pemikiran kritis. Melalui perbedaan pendapat inilah, materi isu kontroversial secara langsung membangkitkan kemampuan berpikir kritis seseorang (Indrawati, 2011).

Dengan adanya masalah kontroversial, hal ini dapat memunculkan keinginan siswa untuk mengenali adanya kontradiksi serta melakukan eksplorasi lebih lanjut terkait hal apa yang menyebabkan kontradiksi tersebut lalu melakukan proses klarifikasi (Rosyadi, 2021). Sejalan dengan hal itu, disebutkan juga bahwa masalah kontroversial ini merupakan suatu keadaan yang dapat memunculkan perdebatan dalam hal sudut pandang seseorang (Rosyadi, 2021). Dalam prosesnya menyelesaikan masalah kontroversial, peran guru menjadi seorang penengah. Dalam penelitian yang dilakukan oleh (Pinzón dkk., 2022) menyatakan bahwa guru tidak memberi kesempatan bagi siswa untuk berbagi ketidakpahaman mereka pada suatu proses diskusi, melainkan memfokuskan dalam menyajikan strategi serta solusi yang benar saja. Di sisi lain, kemampuan atau proses berpikir kritis siswa muncul ketika menyelesaikan masalah kontroversial sesuai penelitian oleh Mueller & Yankelewitz (2014).

Keterampilan Berpikir Kritis Matematis

Seseorang dikatakan berpikir kritis apabila mampu memperoleh suatu pengetahuan dengan hati-hati, tidak mudah menerima pendapat namun mempertimbangkan menggunakan penalaran, sehingga kesimpulannya mampu dipertanggungjawabkan (Abdullah, 2013). Berpikir kritis melatih kemampuan berpikir (kognitif) untuk mengevaluasi dan menganalisis secara rasional mengenai semua informasi, masukan, pendapat, serta ide yang ada, selanjutnya diikuti dengan merumuskan kesimpulan dan mengambil suatu keputusan (Teli, 2021). Berpikir kritis merupakan proses dalam mengaplikasikan rasional, kegiatan berpikir tinggi, yang meliputi analisis, mensintesis, mengenal permasalahan dan pemecahannya, menyimpulkan, serta mengevaluasi (Indrawati, 2011). Berpikir kritis penting untuk siswa karena mampu meningkatkan sikap rasional serta memilih pilihan terbaik bagi dirinya sendiri (Farib dkk., 2019). Ucapan tersebut diperkuat dengan adanya permintaan zaman yang mengharuskan setiap orang untuk memilah, memilih, dan memanfaatkan informasi bagi keberlangsungan hidupnya. Hal ini dipertegas oleh Jumaisyaroh (2014) menyatakan pentingnya menumbuhkan kebiasaan berpikir kritis matematis sejak dini sehingga mampu bersifat rasional dalam mencermati persoalan-persoalan dalam kehidupan sehari-hari.

Berpikir kritis dalam matematika terkait satu sama lain dengan cara berpikir siswa dalam membangun pemikiran pengetahuan matematika (Farib dkk., 2019). Dalam hal ini, matematika berperan penting dalam mencetak serta mengembangkan bahkan mempertahankan keterampilan untuk berpikir secara nalar, logis, sistematis maupun kritis (Tanjung, 2019). Penelitian yang dilakukan oleh Aizikovitsh-Udi & Cheng (2015) menegaskan bahwa pengaplikasian berpikir kritis dalam proses instruksi matematika berdampak dalam meningkatnya prestasi proses belajar siswa. Tahap penyajian data dalam penelitian terkait dengan berpikir kritis ini berdasarkan dengan enam indikator berpikir kritis IDEALS, yang

terdiri dari: (1) *Identify* yaitu mengidentifikasi persoalan pada soal yang diberikan dengan menyebutkan pokok permasalahan, (2) *Define* yaitu mendefinisikan permasalahan pada soal yang diberikan dengan menyebutkan berbagai fakta yang membatasi permasalahan tersebut, (3) *Enumerate* yaitu Mengumpulkan berbagai solusi pemecahan masalah dengan menyebutkan berbagai pilihan solusi dan penyelesaian yang logis, (4) *Analyze* yaitu Mengkaji berbagai pilihan solusi pemecahan masalah untuk menentukan solusi terbaik, (5) *List* yaitu Menyampaikan pendapat berdasarkan fakta/bukti yang relevan terkait solusi terbaik yang dipilih, dan (6) *Self-Correct* yaitu Meneliti atau memastikan kembali keseluruhan langkah penyelesaian mulai dari awal sampai akhir (Rosyadi, 2021).

METODE PENELITIAN

Penelitian ini merupakan suatu penelitian deskriptif menggunakan pendekatan kualitatif. Penelitian deskriptif sebagai penelitian dengan menggunakan variabel penelitian bersifat mandiri, artinya variabel yang diteliti tersebut tidak perlu dilakukan perbandingan atau menghubungkan dengan variabel yang lain (Abdullah, 2018). Dalam penelitian ini, variabelnya tidak melakukan perbandingan atau mencari hubungan terhadap variabel lainnya. Pendekatan kualitatif yang digunakan datanya bersifat deskriptif berupa kata-kata atau gambar (Abubakar, 2021). Variabel ditentukan secara random atau acak. Dengan data yang digunakan berupa data hasil wawancara didukung dengan gambar atau dokumentasi saat melaksanakan penelitian. Penelitian ini dilaksanakan di SMA N 1 Singaraja yang berlokasi di Jalan Pramuka No. 4, Desa/Kelurahan Banjar Bali, Kecamatan Buleleng, Kabupaten Buleleng, Bali, pada Selasa, 1 November 2022 pukul 13.00-selesai.

Metode *purposive sampling* digunakan dalam penentuan subjek penelitian*,* dimana penentuan subjek didasarkan pada ciri-ciri, sifat atau karakteristik tertentu dari populasi yang didasarkan adanya tujuan tertentu sehingga sampel dari penelitian merupakan subjek yang memenuhi ciri-ciri, sifat atau karakteristik tertentu yang terdapat pada populasi (Hikmawati, 2020). Penelitian ini melibatkan siswa kelas X MIPA 1. Kemudian, dipilih siswa dengan ciri-ciri mengalami masalah kontroversial setelah menyelesaikan permasalahan matematis yang diberikan. Permasalahan yang dialami yaitu adanya perbedaan jawaban pada ketiga siswa, serta adanya penolakan jawaban oleh satu subjek terhadap jawaban dari subjek lainnya.

Instrumen penelitian ini terdiri dari peneliti itu sendiri yang menurut Anggito & Setiawan (2018: 76) bahwa “peneliti dalam penelitian kualitatif sebagai instrumen penelitian karena berfungsi untuk menetapkan fokus penelitian, memilih informan sebagai sumber data, melakukan pengumpulan data, menilai kualitas data, analisis data, menafsirkan data, dan membuat kesimpulan dari data yang telah ditemukan di lapangan”. Selain itu, lembar kerja berisi permasalahan kontroversial berbentuk uraian (*essay*), hasil tes siswa, dan hasil wawancara menjadi salah satu instrumen dalam penelitian ini. Berikut merupakan instrumen lembar kerja yang tersaji pada Gambar 1.

Masalah:

Diketahui $\sqrt{x}^{3m} - \sqrt{y}^{3m} = (\sqrt{x}^{m} - \sqrt{y}^{m})(\sqrt{x}^{2m} + \sqrt{x}^{m}\sqrt{y}^{m} + \sqrt{y}^{2m})$. Jika $\sqrt{x} = \sqrt{y}$, maka sederhanakan persamaan tersebut!

Jawab:

$$\sqrt{x}^{3m} - \sqrt{y}^{3m} = (\sqrt{x}^{m} - \sqrt{y}^{m})(\sqrt{x}^{2m} + \sqrt{y}^{m}\sqrt{x}^{m} + \sqrt{y}^{2m})$$

Substitusikan $\sqrt{x} = \sqrt{y}$:

$$\sqrt{y}^{3m} - \sqrt{y}^{3m} = (\sqrt{y}^{m} - \sqrt{y}^{m})(\sqrt{y}^{2m} + \sqrt{y}^{m}\sqrt{y}^{m} + \sqrt{y}^{2m})$$

$$\sqrt{y}^{2m}\left(\sqrt{y}^{m} - \sqrt{y}^{m}\right) = (\sqrt{y}^{m} - \sqrt{y}^{m})(\sqrt{y}^{2m} + \sqrt{y}^{2m} + \sqrt{y}^{2m})$$

Kedua ruas dibagi $\left(\sqrt{y}^{m} - \sqrt{y}^{m}\right)$:

$$\sqrt{y}^{2m} = (\sqrt{y}^{2m} + \sqrt{y}^{2m} + \sqrt{y}^{2m})$$

$$\sqrt{y}^{2m} = 3\sqrt{y}^{2m}$$

$$y^{m} = 3y^{m}$$

Kedua ruas dibagi y^{m} :

$$1 = 3$$

A. Menurut Anda, apakah jawaban tersebut masuk akal? Jelaskan!

B. Jika jawaban tersebut tidak masuk akal, maka berikan jawaban yang menurut Anda masuk akal?

Gambar 1. Masalah Kontroversial Matematis

Pengumpulan data dalam penelitian ini adalah tes berbentuk pertanyaan esai (uraian) yang memuat permasalahan kontroversial dan wawancara tidak berstruktur. Wawancara ini bersifat bebas, artinya tanpa menggunakan pedoman sistematis dan lengkap dan hanya berupa garis besar dari permasalahan (Abdussamad, 2021). Kemudian, model *Miles* dan *Huberman* digunakan sebagai teknik dalam menganalisis data penelitian yang dilakukan melalui: (1) tahap reduksi data yang menurut Sidiq & Choiri (2019) menyatakan bahwa "mereduksi data berarti merangkum, memilih hal-hal yang pokok, memfokuskan pada hal-hal yang penting, serta dicari tema dan polanya" sehingga data hasil tes dan wawancara yang dilakukan pada ketiga subjek penelitian pada Selasa, 1 November 2022 akan direduksi untuk difokuskan dengan tujuan penelitian, (2) tahap penyajian data dilakukan secara deskriptif berdasarkan enam indikator berpikir kritis IDEALS, dan (3) tahap penarikan kesimpulan dari penyajian data hasil tes dan wawancara.

HASIL DAN PEMBAHASAN

Pengkodean subjek penelitian untuk inisial MS sebagai subjek 1 (S1), inisial S sebagai subjek 2 (S2), dan inisial IND sebagai subjek 3 (S3). Berdasarkan hasil analisis data, tes dan wawancara, didapatkan kemampuan berpikir kritis siswa dalam menyelesaikan masalah kontroversial matematika untuk keenam indikator berpikir kritis IDEALS sebagai berikut.

Identify

Hasil wawancara kepada S1, S2, dan S3 dituliskan sebagai berikut.

Tabel 1. Hasil Wawancara 1 kepada Ketiga Subjek

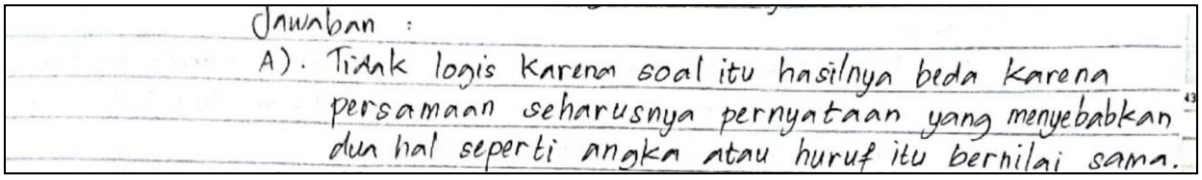
Subjek	Hasil Wawancara
S1	"Tidak logis, karena soal itu hasilnya berbeda. Karena persamaan kan seharusnya pernyataan yang menyebabkan dua hal seperti angka atau huruf itu bernilai sama"
S2	"Menurut saya tidak masuk akal, karena dari jawaban tersebut diperoleh $1 = 3$ padahal $1 \neq 3$"
S3	"Tidak. Karena samakan terlebih dahulu ruas kanan dengan ruas kiri lalu substitusi $\sqrt{x} = \sqrt{4}$. Maka hasilnya akan sama antara ruas kanan dan kiri"

Dari wawancara tersebut, dapat ditarik kesimpulan sebagai berikut.

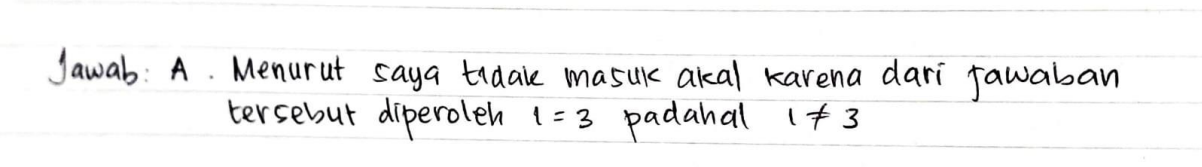
Tabel 2. Kesimpulan Hasil Wawancara 1 kepada Ketiga Subjek

Subjek	Kesimpulan Hasil Wawancara
S1	Menyebutkan pokok permasalahan pada masalah yang diberikan, yaitu menyederhanakan persamaan agar bernilai sama.
S2	Menyebutkan pokok permasalahan pada masalah yang diberikan, yaitu persamaan harus disederhanakan ulang karena pada soal diketahui bahwa persamaan tersebut belum sama ($1 \neq 3$).
S3	Menyebutkan pokok permasalahan pada masalah yang diberikan, yaitu ruas kanan dan ruas kiri tidak sama.

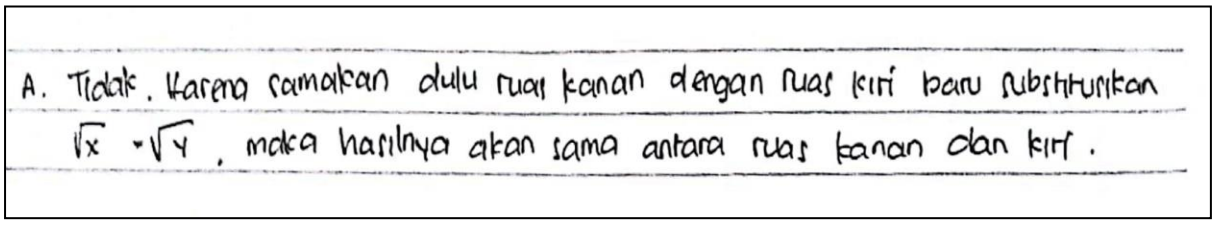
Dari kesimpulan hasil wawancara pada S1, S2, dan S3 menunjukkan pada tahap *identify*, ketiga subjek mampu mengidentifikasi permasalahan pada soal yang diberikan dengan menyebutkan pokok permasalahan. Selanjutnya, jawaban jawaban bagian A dari S1, S2, dan S3 yang disajikan pada Gambar 2, Gambar 3, dan Gambar 4 sebagai berikut.


Jawaban :
A). Tidak logis karena soal itu hasilnya beda karena persamaan seharusnya pernyataan yang menyebabkan dua hal seperti angka atau huruf itu bernilai sama.

Gambar 2. Jawaban Bagian A dari S1


Jawab: A. Menurut saya tidak masuk akal karena dari jawaban tersebut diperoleh $1 = 3$ padahal $1 \neq 3$

Gambar 3. Jawaban Bagian A dari S2

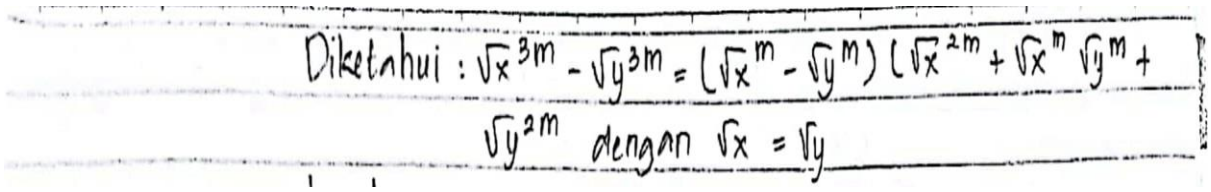

A. Tidak. Karena samakan dulu ruas kanan dengan ruas kiri baru substitusikan $\sqrt{x} = \sqrt{y}$, maka hasilnya akan sama antara ruas kanan dan kiri.

Gambar 4. Jawaban Bagian A dari S3

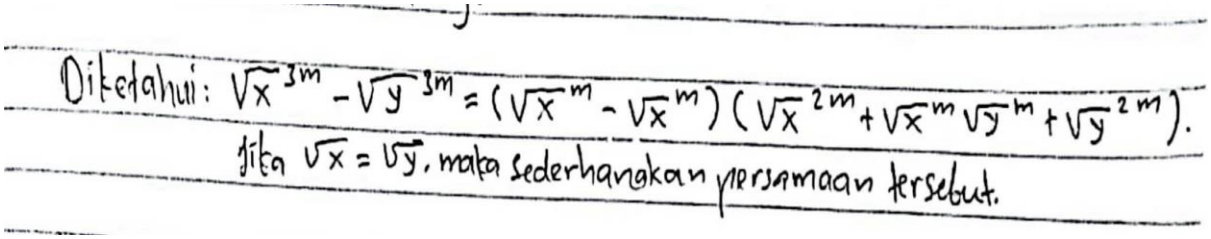
Berdasarkan jawaban S1, S2, dan S3 untuk soal bagian A pada tahap *identify,* ketiga subjek mampu mengidentifikasi jawaban pada soal yang diberikan itu masuk akal atau tidak.

Define

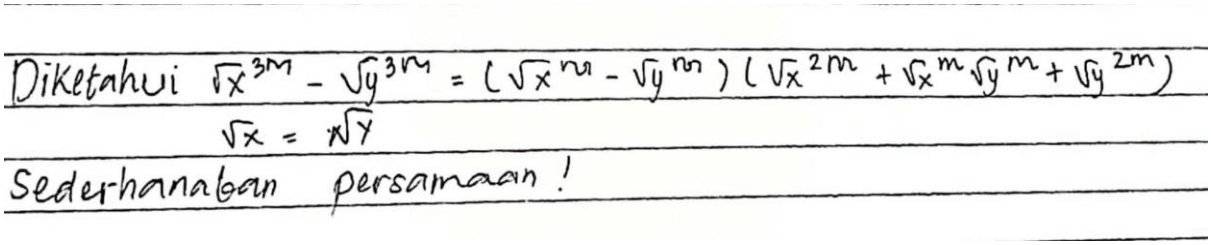
Jawaban dari S1, S2, dan S3 mengenai apa yang diketahui dan ditanyakan pada soal sebagai berikut.



Gambar 5. Jawaban dari S1



Gambar 6. Jawaban dari S2



Gambar 7. Jawaban dari S2

Berdasarkan jawaban S1, S2, dan S3 terkait hal yang diketahui dan ditanyakan dari soal untuk tahap *define,* ketiga subjek mampu mendefinisikan permasalahan dengan menyebutkan berbagai informasi yang diketahui maupun yang ditanyakan. Kemudian, dilakukan wawancara kepada S1, S2, dan S3 dan ditarik kesimpulan bahwa ketiga subjek mengetahui informasi apa saja yang terdapat pada soal. Namun, ketika ketiga subjek tersebut ditanya bagaimana caranya menuliskannya mereka menjawab dengan menulis ulang soalnya.

Enumerate

Tabel 3. Hasil Wawancara 2 kepada Ketiga Subjek

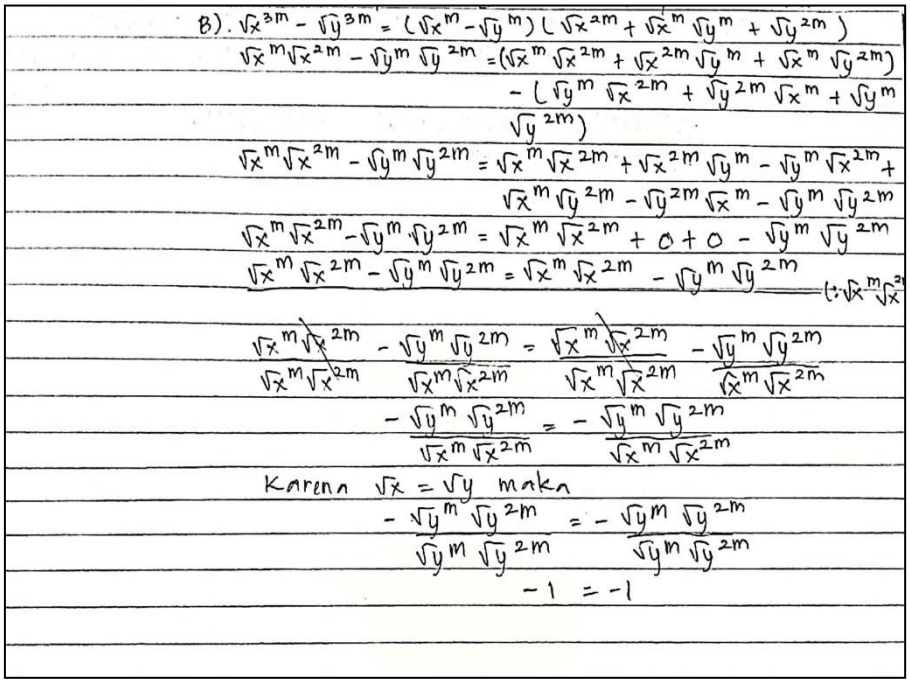
Subjek	Hasil Wawancara
S1	"saya menyederhanakan persamaannya setelah itu substitusi nilai $\sqrt{x} = \sqrt{y}$"
S2	"saya menggunakan konsep $x^3 - y^3 = (x-y)(x^2+xy+y^2)$ untuk menyelesaikan permasalahan pangkat tiga sesuai dengan soal"
S3	"saya hanya menyederhanakan salah satu ruas pada soal, agar menemukan bentuk paling sederhana di salah satu ruas"

Berdasarkan wawancara yang dilakukan kepada S1, S2, dan S3 disimpulkan bahwa ketiga subjek telah menemukan strategi penyelesaian masalah yang menurut mereka masuk

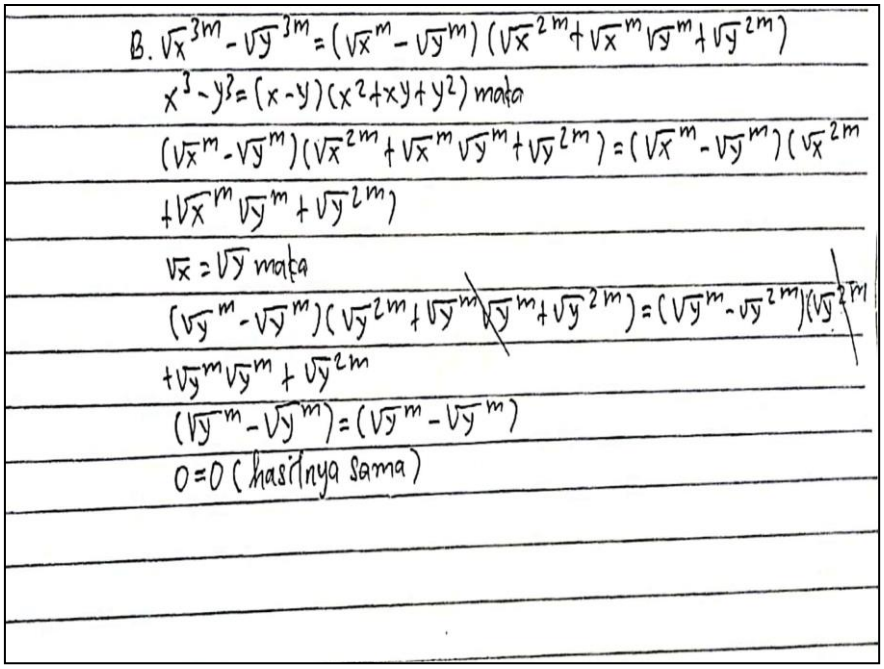
akal. Hal tersebut karena beberapa pilihan strategi penyelesaian masalah yang ditemukan tidak membuat ruas kanan dan ruas kiri dari persamaan tersebut bernilai sama.

Analyze

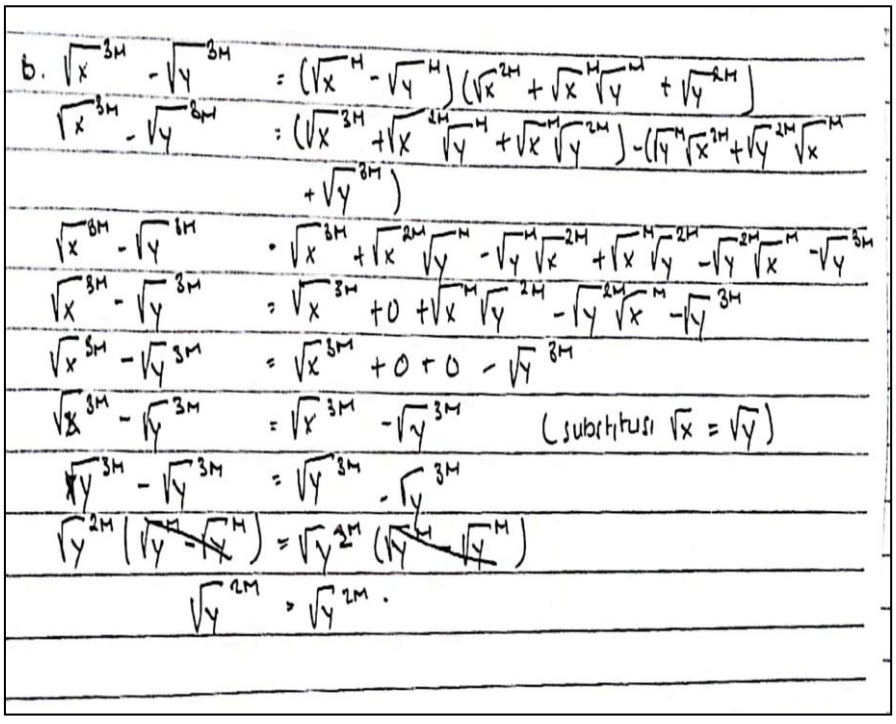
Berdasarkan wawancara kedua yang dilakukan kepada ketiga subjek, mereka menemukan strategi dalam penyelesaian masalah kontroversial yang diberikan. Terdapat perbedaan analisis yang dilakukan oleh ketiga subjek. Jawaban bagian B dari S1, S2, dan S3 menunjukkan analisis dari strategi penyelesaian masalah yang digunakan sebagai berikut.



Gambar 8. Jawaban Bagian B dari S1



Gambar 9. Jawaban Bagian B dari S2



Gambar 10. Jawaban Bagian B dari S3

Berdasarkan jawaban S1, S2, dan S3 untuk soal bagian B pada tahap *analyze,* ketiga subjek menggunakan strategi penyelesaian masalah yang berbeda untuk dianalisis dalam menemukan solusi yang masuk akal dari permasalahan yang diberikan.

List

Hasil wawancara kepada S1, S2, dan S3 disimpulkan sebagai berikut.

Tabel 4. Kesimpulan Hasil Wawancara 2 kepada Ketiga Subjek

Subjek	Kesimpulan Hasil Wawancara
S1	menyebutkan alasan menggunakan cara dan jawaban tersebut karena untuk menyederhanakan persamaan agar bernilai sama harus dengan menyamakan ruas kiri dengan ruas kanan, kemudian menyederhanakan. Selanjutnya, substitusi $\sqrt{x} = \sqrt{y}$.
S2	menyebutkan alasan menggunakan cara dan jawaban tersebut karena untuk menyamakan persamaan memerlukan konsep $x^3 - y^3 = (x-y)(x^2+xy+y^2)$ yang ada kaitannya dengan soal.
S3	menyebutkan alasan menggunakan cara dan jawaban tersebut karena ruas kanan dan ruas kiri supaya sama memerlukan menyederhanakan salah satu ruas agar kedua ruas dalam bentuk yang paling sederhana sehingga mudah untuk diselesaikan.

Dari kesimpulan hasil wawancara pada S1, S2, dan S3 menunjukkan pada tahap *list*, ketiga subjek mampu menyebutkan alasan menggunakan strategi penyelesaian masalah yang digunakan untuk menjawab pertanyaan bagian B.

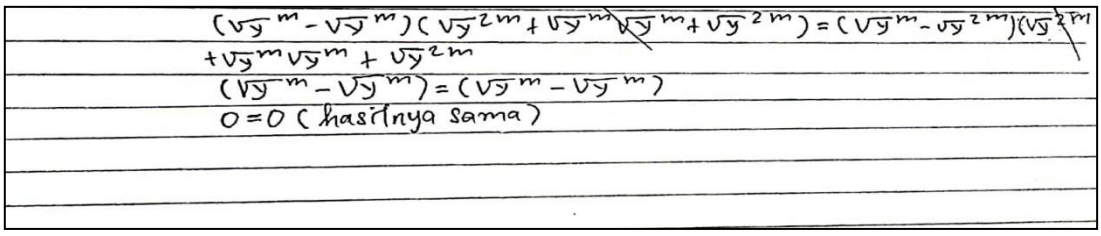
Self-Correct

Hasil wawancara kepada S1, S2, dan S3 disimpulkan sebagai berikut.

Tabel 5. Kesimpulan Hasil Wawancara 3 kepada Ketiga Subjek

Subjek	Kesimpulan Hasil Wawancara
S1	mengatakan bahwa setelah menyelesaikan masalah yang diberikan telah melakukan pengecekan kembali terkait perhitungan sehingga sudah sangat yakin dengan solusi dari masalah tersebut.
S2	mengatakan bahwa telah melakukan pengecekan kembali proses penyelesaian masalah dengan memberikan penekanan di akhir jawabannya, yaitu hasilnya sama.
S3	mengatakan bahwa saat memberikan alasan terkait menggunakan cara dan jawaban tersebut juga memerlukan pengecekan kembali sebagai bahan argumentasi.

Selanjutnya, jawaban dari S2 terkait penekanan pada akhir jawabannya disajikan dalam gambar 11 sebagai berikut.



Gambar 11. Penekanan di Akhir Jawaban oleh S2

Berdasarkan kesimpulan hasil wawancara pada S1, S2, dan S3 menunjukkan pada tahap *self-correct*, ketiga subjek sudah meneliti atau mengecek kembali masing-masing strategi penyelesaian masalah yang mereka gunakan. Salah satunya dengan adanya penekanan pada akhir jawaban oleh S2 yang disajikan pada Gambar 11 di atas.

Dari tes maupun wawancara yang sudah dilakukan diatas, dapat dilihat kemampuan berpikir kritis siswa dalam menyelesaikan masalah kontroversial matematika untuk enam indikator berpikir kritis IDEALS: pertama, pada tahap *identify* dari kesimpulan hasil wawancara diperoleh bahwa S1, S2, dan S3 mampu mengidentifikasi permasalahan pada soal yang diberikan dengan menyebutkan pokok permasalahan yang disimpulkan, yaitu sederhanakan persamaan karena ruas kanan dan ruas kiri tidak bernilai sama. Hasil wawancara ini searah penelitian yang dilakukan Rosyadi (2021) menyatakan bahwa dari kutipan percakapan antara peneliti (P) dengan subjek penelitian (S) sudah dapat menyebutkan pokok permasalahan "sederhanakan". Penelitian Kaliky & Juhaevah (2018) juga menyatakan bahwa dalam proses menyelesaikan masalah identitas trigonometri dapat memenuhi berpikir kritis sebagai indikator pertama, yaitu merumuskan permasalahan utama dari suatu masalah. Selain itu, jawaban bagian A dari ketiga subjek telah menunjukkan bahwa mereka mampu mengidentifikasi jawaban pada soal yang diberikan itu tidak masuk akal sehingga dapat menentukan konsep penyelesaian masalah yang diperlukan. Hal tersebut sesuai dengan penelitian Lestari dkk. (2019) yang menemukan bahwa dari 26 siswa kelas VIII SMP IT Bina Ilmi Palembang terdapat 14 siswa mampu memenuhi indikator kemampuan berpikir kritis dalam memahami soal sehingga dapat menentukan konsep dan perhitungan yang harus digunakan dalam menyelesaikan soal tersebut.

Kedua, pada tahap *define* yang ditunjukkan dari jawaban ketiga subjek diperoleh bahwa S1, S2, dan S3 mampu mendefinisikan permasalahan yang diberikan dengan menyebutkan berbagai informasi yang dibutuhkan. Namun, S1 hanya menyalin kembali terkait yang diketahui tanpa menuliskannya dengan kalimat sendiri, begitupun dengan S2 dan S3 hanya menyalin terkait diketahui dan ditanyakan pada soal tanpa menuliskannya kembali dengan kalimat sendiri. Begitu pun dengan hasil wawancara dari S1, S2, dan S3 sudah mampu mengetahui informasinya apa saja yang ada pada soal. Namun, jika ditanya mengenai penulisan yang diketahui dan ditanya pada soal maka mereka hanya menjawab dengan menulis ulang soalnya. Penelitian (Syafruddin dan Pujiastuti 2020) juga menyimpulkan pada kemampuan klasifikasi sebagai salah satu indikator kemampuan berpikir kritis siswa yang didasarkan pada hasil tes dan wawancara siswa terkait pemahaman serta pengetahuan terhadap soal, namun kurang lengkap dalam penulisannya dikarenakan ada siswa yang hanya menyalin soalnya saja.

Ketiga, dari hasil analisis wawancara pada tahap *enumerate* disimpulkan bahwa ketiga subjek hanya menemukan satu strategi penyelesaian masalah yang menurut mereka masuk akal. Hal tersebut karena beberapa pilihan strategi penyelesaian masalah yang ditemukan tidak membuat ruas kanan dan ruas kiri dari persamaan tersebut bernilai sama. Oleh karena itu, ketiga subjek pada tahap *analyze* hanya menggunakan satu strategi penyelesaian masalah tersebut untuk dianalisis dalam menemukan solusi yang masuk akal dari permasalahan yang diberikan. Temuan ini searah terhadap penelitian (Alifiani & Nurul Hasana, 2020) yang menyatakan bahwa dalam menganalisis proses berpikir kritis subjek 1 mampu memperhitungkan strategi yang tepat berbantuan *deepen* dan *enumerate* yaitu pada soal

tes nomor 3. Namun, subjek 1 (S1) tersebut terfokus pada satu strategi saja sehingga subjek tersebut hanya mengandalkan strategi itu saja untuk menemukan solusinya. Penelitian Alghifari (2020) juga menemukan bahwa subjek S2 yang termasuk memiliki kemampuan tinggi dalam berpikir kritis pada tahap *enumerate* dan *analyze* dari hasil jawabannya hanya menggunakan cara kombinasi untuk menjawab soal. Hasil wawancara dengan S2 tersebut menyebutkan jika ia tidak memiliki jalan lain dalam menyelesaikan soal tersebut.

Kemudian, pada tahap *list* dari kesimpulan hasil wawancara diperoleh bahwa S1, S2, dan S3 mampu menyebutkan alasan menggunakan strategi tersebut dalam menyelesaikan pertanyaan bagian B. Jadi, dapat disimpulkan bahwa ketiga subjek sudah mampu dalam memberikan alasan logis terkait penggunaan strategi penyelesaian tersebut. Hal ini sejalan terkait penelitian (Munawwarah, Laili, dan Tohir 2020) yang menunjukkan ketercapaian suatu subjek kelompok tinggi di tahap *list* adalah ketika subjek tersebut mampu dalam memberikan alasan mengapa ia memilih prosedur penyelesaian tersebut.

Selanjutnya, pada tahap *self-correct* dari S1 dari hasil wawancara tersebut mengatakan sangat yakin dengan solusi permasalahannya karena sudah melakukan pengecekan kembali. Sejalan dengan penelitian dari Jannah (2021) ditemukan subjek 01 (S-01) pada indikator keenam berpikir kritis, yaitu mengecek kembali (*self-correct*) telah menjawab lumayan yakin dengan hasil jawabannya. Kemudian, pada S2 dari hasil wawancara mengatakan bahwa telah melakukan pengecekan kembali, tetapi hanya pada hasil akhir saja dan menambahkan penekanan di akhir jawabannya, yaitu hasilnya sama. Penelitian Hidayanti dkk (2020) menyebutkan hal yang sama jika deskripsi berpikir kritis siswa laki-laki kelas VIII.1 SMP Negeri 2 Labakkang dalam memecahkan masalah matematika pada tahap *overview* sudah memeriksa kembali hasil pekerjaannya, tetapi hanya memeriksa hasil akhirnya saja. Lalu, pada S3 mengatakan bahwa saat memberikan alasan terkait menggunakan cara dan jawaban tersebut juga memerlukan pengecekan kembali sebagai bahan argumentasi. Jadi, berdasarkan kesimpulan hasil wawancara diperoleh bahwa S1, S2, dan S3 pada tahap *self-correct* sudah meneliti atau mengecek kembali masing-masing strategi penyelesaian masalah yang mereka gunakan. Salah satunya dengan adanya penekanan pada akhir jawaban oleh S2. Hal ini sinkron dengan penelitian Fatmawati (2018) yang menyatakan pada tingkat kemampuan tinggi yang diwakili oleh dua siswa untuk diwawancarai dengan kode AL dan HA menunjukkan pada masalah dengan pokok bahasan program linier 1, 2, dan 3, AL telah melakukan pengecekan kembali dengan tepat. Begitu pun juga dengan HA dari hasil wawancara menunjukkan telah melakukan pengecekan kembali dengan tepat untuk masalah 1 dan 3. Namun, ternyata untuk masalah 2 terjadi kesalahan dalam menghitung.

KESIMPULAN DAN SARAN

Melalui wawancara yang dilakukan dalam penelitian ini, dapat disimpulkan hal-hal berikut ini. Kemampuan berpikir kritis siswa saat menyelesaikan masalah kontroversial matematika melalui enam indikator berpikir kritis IDEALS, yaitu (1) *identify*, diperoleh bahwa subjek penelitian mampu mengidentifikasi dan menyebutkan pokok permasalahan yang disimpulkan, yaitu sederhanakan persamaan karena ruas kanan dan ruas kiri tidak bernilai

sama, sesuai dengan jawaban ketiga subjek pada bagian A untuk menyederhanakan kedua ruas, (2) *define*, diperoleh subjek mampu mendefinisikan permasalahan pada soal yang diberikan dengan menyebutkan berbagai informasi yang dibutuhkan pada soal. Namun, mereka hanya menyalin kembali mengenai hal yang diketahui serta ditanyakan tanpa menuliskannya kembali dengan kalimat masing-masing, (3) *enumerate*, disimpulkan bahwa ketiga subjek hanya menemukan satu strategi penyelesaian masalah yang menurut mereka masuk akal, (4) *analyze*, ketiga subjek hanya menggunakan satu strategi penyelesaian masalah tersebut untuk dianalisis dalam menemukan solusi yang masuk akal dari permasalahan yang diberikan, (5) *list*, diperoleh bahwa ketiga subjek mampu menyebutkan alasan menggunakan strategi penyelesaian masalah yang digunakan untuk menjawab pertanyaan bagian B, dan (6) *self-correct*, diperoleh bahwa ketiga subjek sudah meneliti atau mengecek kembali masing-masing strategi penyelesaian masalah yang mereka gunakan serta memberikan penekanan pada akhir jawaban.

Subjek dalam penelitian ini hanya menggunakan tiga subjek siswa SMA yang dipilih karena mengalami masalah kontroversial setelah menyelesaikan permasalahan matematis, maka subjek ini masih kurang bervariatif. Oleh karena itu, untuk peneliti berikutnya diharapkan meneliti lebih lanjut dengan subjek penelitian yang lebih bervariatif terhadap siswa SMP maupun SMA dengan diperlukan juga untuk menganalisis kemampuan berpikir kritis dalam menyelesaikan masalah kontroversial matematika dengan partisipasi siswa menurut gendernya yaitu laki-laki dan perempuan serta kelas dengan berpikir tinggi, sedang maupun rendah.

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RESEARCH ON STUDENTS' MATHEMATICAL ABILITY IN LEARNING MATHEMATICS IN THE LAST DECADE: A BIBLIOMETRIC REVIEW

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ABSTRACT

Mathematical ability is a cognitive ability that needs to be developed in every student because the mathematical ability is closely related to solving problems that involve the relationship of numerical symbols with students' cognitive activities. This study aims to look at the description of previous research related to mathematical abilities in learning mathematics in the last decade using bibliometric analysis methods. The data taken from the Scopus database was refined so that it became 157 publications. The United States of America is the most influential country and has high cooperation with other countries in this field. The focus of this research is: 1) ICT, Augmented reality, Computational thinking, and university; 2) mathematical problems, pre-service teachers, and higher education: 3) mathematics abilities, mathematics literacy, and outcomes; 4) high mathematical ability, technology and critical thinking ability. The results of this study can be used as a reference for other researchers.

Keywords: mathematical ability, learning mathematics, bibliometric

INTRODUCTION

Mathematical ability is a very important ability to support individual work results both in the academic field and in daily activities. (Özsoy et al., 2022). Meanwhile, according to (Hassan, 2021) mathematical ability becomes a cognitive ability that can be developed in every student, because it is closely related to solving problems that involve the relationship of numerical symbols with students' cognitive activities. Mathematical ability is defined as a skill possessed by students in completing tasks using concrete objects, abstract symbols, and logical reasoning that can be measured by tests of mathematical abilities (Febriana et al., 2019). According to (Barizah & Jupri, 2019) mathematical ability is a cognitive ability, namely the ability to perform calculations in the formal language of mathematics (non-verbal). So mathematical abilities are skills possessed by individuals in solving a problem by using numerical symbols or by logical reasoning.

Students' mathematical abilities have become the concern of the world of education at this time (Etang & Regidor, 2022). This is in line with what was conveyed by (Chen et al., 2022) that research is often carried out especially in terms of measuring students' mathematical abilities. This means that mathematical abilities have been in great demand

by researchers, especially in the field of education (Gunur et al., 2019). This resulted in an increasing number of publications related to mathematical ability in learning mathematics, giving rise to a large amount of academic literature (Primayanti et al., 2018).

Gaps in mathematical ability were most pronounced before children started school and have widened over time (Willingham, 2021). According to (Xie, 2020) Mathematical ability consists of four main abilities, namely numerical ability, arithmetic ability, geometric ability, and logical reasoning. In learning mathematics these four abilities are very necessary. This is in line with what was stated by (Fawziawati, 2022) that in learning mathematics numerical abilities must be developed and owned by students. The same goes for arithmetic skills (Elofsson et al., 2018), geometric ability (Larkin et al., 2019), and logical reasoning (Bezuidenhout & Henning, 2022).

In collecting existing knowledge, various methods of literature review can be used (Suseelan et al., 2022). One way is by bibliometric analysis. Bibliometric is a statistical method in analyzing publications (Phoong et al., 2022). Meanwhile according to (Zyoud et al., 2022) Bibliometrics is the basis for determining the most popular and most significant publications in a particular field. For researchers, doing bibliometric analysis will be very helpful in determining research gaps and study emphasis (Chen et al., 2019).

An existing research gap in the area of mathematical ability in mathematics learning, in the context of bibliometric research, is a lack of understanding of the trend of publications related to the topic over the last decade (Marchy et al., 2022). Although there are studies that have been conducted, there is no comprehensive bibliometric analysis that tracks and identifies related publications (Ramadhaniyati et al., 2023), influential authors (Sanusi et al., 2023), and institutions' contributions in advancing the understanding of mathematical ability in mathematics learning (Mayani et al., 2022).

In addition, the bibliometric research gap also includes the lack of research that analyzes in detail the dominant research topics, the interconnections between these topics, and the collaboration between the authors involved in the research (Muhammad et al., 2022). By conducting a bibliometric analysis, these gaps can be filled by identifying dominant research trends (Muhammad et al., 2023), describing the network of authors and institutions that work together, and identifying areas that need more attention and research development in the future.

Thus, bibliometric analysis can provide a more comprehensive understanding of the landscape of previous research on mathematical ability in mathematics learning over the last decade, as well as filling existing research gaps in the field. So the researcher seeks to conduct research related to bibliometric analysis in looking at the research landscape from previous studies on mathematical abilities in mathematics learning in the last decade.

LITERATURE REVIEW

Mathematical ability has been interpreted as a multidimensional construct which involves the capacities for quantitative reasoning, causal reasoning, spatial rotation, spatial orientation, and qualitative reasoning (Isnani et al., 2020). Meanwhile according to (Hayyu

et al., 2020) Mathematical aptitudes include reasoning, communication, problem-solving, conceptual comprehension, mathematical understanding, as well as critical and creative thinking. Empirical research on mathematical ability has been extensively conducted in the past (Zandundo et al., 2020). The research was conducted to identify students' mathematical abilities at various levels of education (Bulos, 2021), and how the student's ability to solve math problems (Ernawati, 2020).

Previous research has also often linked mathematical abilities with spatial abilities. As done by (Young, 2018) which examines the relationship between spatial ability and mathematical ability, and what (Xie, 2020) did about meta-analysis related to spatial abilities and mathematical abilities. Further research conducted by (Zetriuslita, 2020) about self-regulates and self-efficacy in terms of students' mathematical abilities. And research related to mathematical abilities conducted by (Sanjaya et al., 2018) about students' thinking processes in solving mathematical problems based on their level of mathematical ability. From these studies, mathematical ability is not only associated with students' cognitive abilities, but also from a behavioral perspective, meaning that this mathematical ability is very interesting for further research.

While a bibliometric analysis is used in this study to illustrate research trends, previous related research is synthesized by analyzing the relevant literature to address the very particular research questions posed. The results of this study will help academics better comprehend the most recent studies on students' mathematical problem-solving in order to help them narrow their research focus.

Aim of the Study

This study attempts to provide the state of the art of research on students' mathematical skills as they acquire mathematics during the last ten years. The following research questions are covered in this study:

1) What are the current trends in research publications ?
2) What are the research citation trends related to mathematical ability in mathematics learning?
3) What is the distribution of publication mapping and relations between countries in research related to mathematical ability in mathematics learning?
4) What is the research focus on mathematical ability in mathematics learning?

METHODOLOGY

In looking for data sources related to "students' mathematical abilities in learning mathematics", researchers used the scopus database because of its very broad interdisciplinary coverage. There are several steps in perfecting the data that has been collected as shown in Figure 1. The first is identification, then followed by screening, eligibility and finally the inclusion step (Moher et al., 2009).

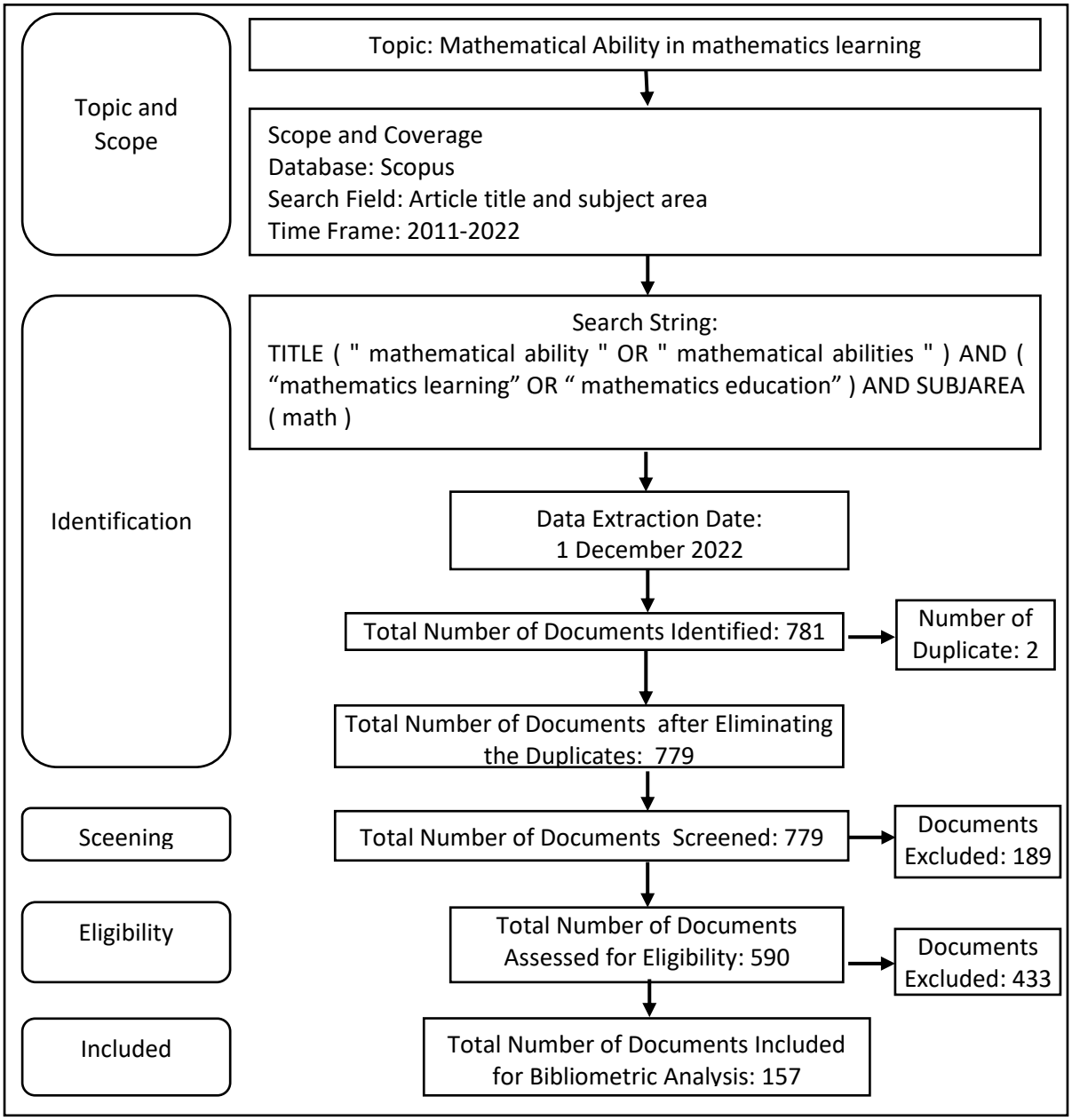

Figure 1. Data Collection Process

Trends in publication citations related to mathematical ability in learning mathematics are separated by year. The average publication citations were also calculated using Microsoft Excel software. As for finding the h-index and g-index of the publication, the researcher uses Publish or Perish (PoP).

In displaying the distribution of publications by country, researchers also use Microsoft Excel software to display a world map with the distribution of publications in various countries. As with the citation trend, to find the h-index and g-index of publications, researchers also use Harzing's Publish or Perish Software. VOSviewer software is used to produce network visualizations that show the relationship between countries.

Analysis of events with keywords related to mathematical ability in learning mathematics was carried out to determine the research focus. The data to be analyzed is taken from the Scopus database which must be processed first. The research focus can be determined from shared keywords visualized by the VOSviewer Software.

RESULT AND DISCUSSION

The number of publications obtained at the inclusion stage was 157 selected publications from 2011 to 2022 at scopus database. The data sources were taken from articles with 98.09% then book chapters with 1.91%. Distribution of publications from 2011 to 2022 as shown in Figure 2 below. The highest number of publications occurred in 2019, namely 21 articles were published that year if presented in 2019 (13.37%), then in 2021 (12.10%).

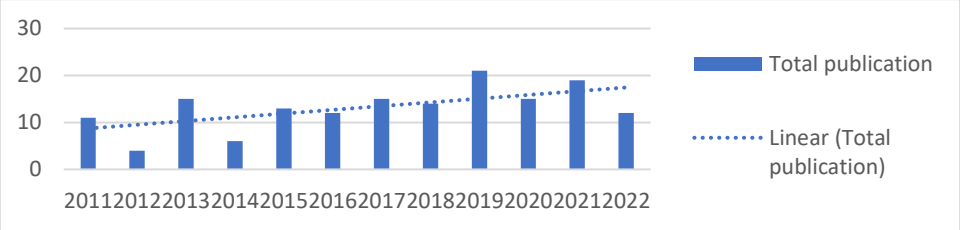

Figure 2. Publications from 2011 to 2022

The increase occurred from 2018 to 2019, namely an increase of 50%. This means that there has been a two-fold increase from the previous number of publications. Judging from the linear line or the publication trend, it shows that publications are increasing every year. The lowest number of publications was in 2012 with only 4 publications.

Citation Trend

The trend of quotations from 2011 to 2022 at scopus database related to students' mathematical abilities in learning mathematics as shown in table 1 is as follows.

Table 1. *Citation Analysis of Publications*

Year	TP	NCP	TC	C/P	C/CP	h	g
2022	12	7	12	1	1,71	2	2
2021	19	8	16	0,84	2	2	3
2020	15	11	102	6,80	9,27	4	10
2019	21	17	139	6,62	8,18	7	11
2018	14	13	126	9	9,69	6	11
2017	15	13	163	10,87	12,54	7	12
2016	12	11	133	11,08	12,09	7	11
2015	13	13	213	16,38	16,38	8	13
2014	6	5	200	33,33	40	5	6
2013	15	15	612	40,80	40,80	10	15
2012	4	4	88	22	22,00	3	4
2011	11	9	112	10,18	12,44	6	10

Notes. TP=total of publication, NCP=number of cited publication, TC=total citations, C/P=average citations per publication, C/CP=average citations per cited pblication, h=h-index, g=g-index

Table 1 above shows that the number of publications cited (NCP) in 2019 was the highest (NCP = 17). The highest total citations were in 2013 with 612 citations, followed by 2015 with 213 citations. The g-index and h-index, which are measured yearly, indicate that in 2013, when the h-index was 10 and the g-index was 15, they were at their greatest levels. This indicates that in 2013, when 15 papers were published with 612 citations and at least 15 publications had each been referenced at least 40 times, it had the greatest influence on research on students' mathematical ability in studying mathematics.

Geographical Distribution of the Publications and Global Collaboration Pattern

The author's country of origin in documents related to mathematical abilities in the Scopus database will be shown in Figures 3 and 4. Figure 3 shows the geographical distribution of publications. Based on this figure, a total of 15 countries, namely countries with more than one publication. Figure 4 shows that the United States is the most influential country in this field. America with 24 articles published (15 percent of total publications).

The Americas, Asia, Australia and Europe have published articles, while the African continent has not published articles related to students' mathematical abilities in learning mathematics in Scopus indexed journals. The Americas are the continent that publishes the most articles, because the country on the American continent, namely the United States, has the highest number of publications.

Figure 3. Geographic Distribution of Publications (Scopus Database)

In Figure 4, shows the pattern of global collaboration based on the author's country of origin which is displayed by network visualization with VOSviewer software, researchers do not set thresholds but researchers only display countries that cooperate with other countries, namely at least 1 collaboration with other countries, from 25 countries it shrinks to 18 countries after the threshold was set, of the 18 countries, the United States, Germany and Australia have the most relationships with other countries, this can be seen from the size of the circle in the countries shown in Figure 4, but not all countries are directly related to these three countries For example, there is an Italian country that is not related or has no links with Germany and Australia. The most important nation in this subject is the United States of America because it has collaborated with all countries that have published articles related to students' mathematical abilities in learning mathematics. Of the 18 countries,

there are 5 clusters. With the largest cluster that is with a red circle. The other clusters are given a color (blue, yellow, green and purple).

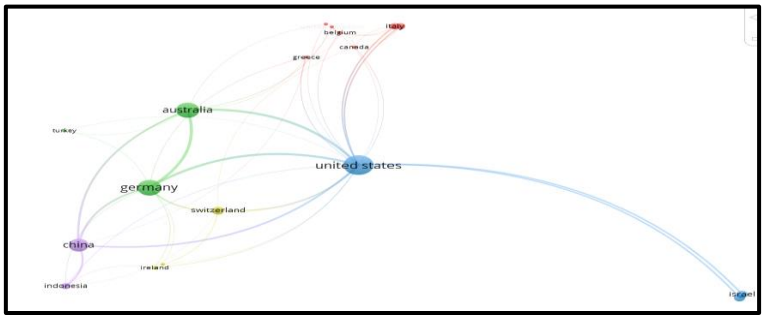

Figure 4. Global Collaboration Patterns (Scopus database)

Research Focus

Analysis of events with keywords was carried out to determine the research focus on students' mathematical abilities in learning mathematics. Researchers set a threshold that is at least 3 publications that contain the same keywords. From these results, the 257 keywords were reduced to 36 keywords.

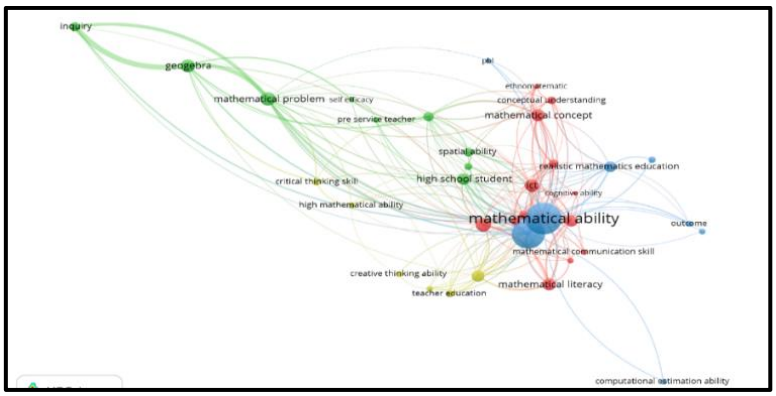

Figure 5. Co-occurrence of keywords (Scopus database)

Figure 5's network visualisation findings demonstrate that there are four clusters with 36 items in the Mathematical Ability in Learning Mathematics category namely, 1) Cluster 1 (red in color) is the largest cluster consisting of 13 items, keywords such as ICT, Augmented reality, Computational thinking and university have the largest circle among the other cluster 1, meaning that the keyword reflects the focus of research related to mathematical ability in learning mathematics; 2) cluster 2 (colored green) consists of 9 items with the keywords mathematical problem, pre service teacher and higher education have a larger circle than the others, meaning that these keywords are the focus of research; 3) cluster 3 (dark blue) consists of 8 items where the circles on the keywords mathematics ability, mathematics literacy and outcomes are the largest in the cluster meaning these keywords are the focus of research; 4) cluster 4 (yellow) consists of 6 items with the keywords high mathematical ability, technology and critical thinking ability has the largest circle among cluster 4, meaning that these keywords are the focus of the fourth research.

What are the current trends in research publications

The trend of publications related to mathematical abilities in learning mathematics from 2011 to 2022 shows that publications have increased from 2018 to 2019, the highest number of publications occurred in 2019 where there were 21 publications published. This is in accordance with what was stated by (Etang & Regidor, 2022) that the number of publications tends to increase from year to year related to research on mathematical abilities in learning.

The number of publications in 2019 totaled 21, but only 17 have been cited at least once, meaning that there are 4 publications that have not been cited at all. The h-index and g-index values in 2013 were the largest compared to other years. 2013 was also the year with the highest number of citations, namely 612 citations. The number of documents in 2013 was 15 documents. The 15 documents can be seen in table 2.

What is the citation trend of research related to mathematical abilities in mathematics learning?

The publication that has the highest number of citations is in 2013 which is shown in table 2 with a total of 612 citations. In 2013 there were only 15 published articles. Research conducted by (Starr, 2013) with the title "Number sense in infancy predicts mathematical abilities in childhood" has been cited 225 times, meaning that the number of citations in one article has exceeded 35% of the number of citations in that year. Article written by (Starr, 2013) widely cited because the article supports the theory that mathematics is built on an intuitive sense of numbers that precedes language and validates many earlier studies claiming to show number sense in children. This research also demonstrates that nonverbal number sense is correlated with math ability in children and adults.

Table 2. Article published in 2013

No	*Author (year)*	*Sources*	*Citation*
1	(Starr, 2013)	*Proceedings of the National Academy of Sciences of the United States of America*	225
2	(Kattou et al., 2013)	*ZDM - International Journal on Mathematics Education*	73
3	(Ven, 2013)	*Learning and Individual Differences*	50
4	(Muldoon et al., 2013)	*Developmental psychology*	46
5	(Penner-Wilger & Anderson, 2013)	*Frontiers in Psychology*	43
6	(Tibber, 2013)	*Vision Research*	37
7	(Guillaume et al., 2013)	*Acta Psychologica*	36
8	(Fogliati, 2013)	*Psychology of Women Quarterly*	29
9	(Ludwig et al., 2013)	*Translational Psychiatry*	22
10	(Edwards, 2013)	*Child Neuropsychology*	21
11	(Vicente, 2013)	Cultura and Educación	9
12	(Kessels & Steinmayr, 2013)	*Zeitschrift Fur Padagogische*	8
13	(Barbosa, 2013)	*International Journal of Instruction*	6

No	*Author (year)*	*Sources*	*Citation*
14	(Han, 2013)	*Magnetic Resonance Imaging*	4
15	(Solovieva et al., 2013)	*Cultura and Educación*	3

Article written by (Kattou et al., 2013) in 2013 it became the publication with the second most citations with 73 citations. This article has received a lot of attention since it looks at the structure of the link between mathematical creativity and ability, as well as if there is a relationship at all. Data research showed a relationship between mathematical creativity and aptitude that is favourable. A subcomponent of mathematical aptitude is mathematical creativity, according to the confirmatory factor analysis. Additionally, latent class analysis reveals that three distinct kinds of pupils with various mathematical aptitudes may be found. The three kinds of pupils who differ in mathematical inventiveness are also represented in this group of kids with a range of mathematical abilities. According to the yearly calculations for the g-index and h-index, 2013 also had the highest g-index and h-index readings. From table 2 above, 15 articles published in 2013 which have been widely cited can be used as references for further research that will examine mathematical abilities in learning mathematics.

What is the geographical distribution of the publication and the collaboration pattern among countries in research related to mathematical abilities in mathematics learning?

Two countries, namely the United States and Australia, are countries with the highest number of publications related to mathematical ability in learning mathematics. The top country by number of publications is the United States. The number of publications from the United States is 15% of the total, which is 24 publications. The country with the top order based on the number of publications is the United States of America. The total number of publications from the United States is 15% of the total, namely 24 publications.

Relations or collaboration between countries are also dominated by the United States, with two other countries namely Germany and Australia with a total of 26, 9 and 8 links respectively, where all countries that publish articles related to mathematical abilities in learning mathematics have collaborated with other countries. United States of America.

What are the focus of the research on mathematical abilities in mathematics learning?

The focus of research related to mathematical abilities in learning mathematics is divided into four parts, namely 1) ICT, Augmented reality, Computational thinking and university; 2) mathematical problems, pre service teachers and higher education: 3) mathematics abilities, mathematics literacy and outcomes; 4) high mathematical abilities, technology and critical thinking ability.

The first research focus is Augmented reality, Computational thinking and university, as research conducted by (Anistyasari et al., 2019) which analyzes the effective factors namely gender, mathematical ability, ICT, and language skills as predictors of computational thinking. The results of this study indicate that the level of computational thinking is

sequentially influenced by math ability, language skills, gender, and ICT literacy. This means that mathematical abilities and ICT affect computational thinking. Further research conducted by (Yunianto & Cahyono, 2021) who have described the development of learning media to improve the Mathematical Ability of mobile-assisted students using augmented reality and to determine the effectiveness of mobile-assisted learning media using augmented reality in team assisted individualization learning to improve student abilities. (Yunianto & Cahyono, 2021) also explained the importance of using technology in education that the main purpose of using technology is to increase the efficiency and effectiveness, transparency and accountability of learning, especially at the college or university level. For this reason, future research can make this a research theme related to mathematical ability.

The second research focus is mathematical problem, pre service teacher and higher education. According to (Yusupova, 2021) Students' mathematical abilities can be seen from their work in solving a mathematical problem or by analyzing written problem solving. Furthermore, the results of research conducted by (Agoro, 2015) shows that the four factors of mathematical ability provide the highest contribution (β=.221) followed by an instructional strategy (β=.217), then gender (β=.074), while the method of entry gives the lowest contribution to the performance of the pre service teacher. According to (Boyd et al., 2014) teaching mathematics with confidence is associated with teachers' beliefs about their mathematical ability. For this reason, it is necessary for further researchers to choose research themes related to the mathematical abilities of pre-service teachers.

The third research focus is mathematics ability, mathematics literacy and outcomes. Research conducted by (Nurutami et al., 2018) said that students with high mathematical abilities could achieve PISA mathematical literacy levels 2 and level 4, students with average mathematical abilities could achieve PISA Mathematical Literacy level 2, and students with low mathematical abilities could not reach levels of mathematical literacy 2.3. or level 4 PISA. The last research focus is high mathematical ability, technology and critical thinking ability. Study (Benyamin et al., 2021) describes students' critical thinking abilities in solving word problems in terms of gender and mathematical ability, then the study suggests that further researchers conduct research at a higher level with more research subjects or on other variables.

CONCLUSION

Based on results and discussion, the publication trend related to mathematical abilities in learning mathematics has increased from 2018 to 2019. The highest number of citations was in 2013 with 612 citations. Articles about this field seen from the geographic distribution by country show that the United States of America is the most influential country in this field which has collaborated with many countries. The focus of research in this field is as follows: 1) ICT, Augmented reality, Computational thinking and university; 2) mathematical problems, pre service teachers and higher education: 3) mathematics abilities, mathematics literacy and outcomes; 4) high mathematical ability, technology and critical thinking ability. The four research focuses are research gaps and an overview of the

research landscape related to mathematical ability in learning mathematics which encourages future researchers to determine their research focus and theme. This means that in the last decade the description of research on mathematical ability in mathematics learning has attracted great interest from researchers, they focus on computational abilities and research at the university level.

The limitations of this research are; 1) the data analyzed comes from the Scopus database, so there are many other databases that can be used such as Wos and others; 2) this research only discusses mathematical abilities in learning mathematics, so there are many other fields of education that can be further investigated; 3) data in this study taken on December 1, 2022 cannot reflect research after that time, so there may be slight differences

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PENERAPAN SISTEM AMONG SEBAGAI IMPLEMENTASI MERDEKA BELAJAR DALAM MENINGKATKAN KEAKTIFAN BELAJAR SISWA PADA PEMBELAJARAN DARING [IMPLEMENTING THE AMONG SYSTEM TO FOSTER INDEPENDENT LEARNING AND INCREASE STUDENT LEARNING ACTIVENESS DURING ONLINE LEARNING]

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ABSTRACT

Student learning activeness is very important in the learning process. However, student learning activeness remains a problem at many schools. Students observed by researchers during the field practice programme had low activeness. Based on the results of the total percentage of student learning activeness observation sheets, 37% of the group belongs in the less active category. Students' learning activeness is influenced by the approach used by the teacher during the learning process. As an implementation of the independent learning concept, the Among learning approach provides freedom and space for students to be actively involved. The freedom concept certainly does not deviate from the correct understanding of a Christian perspective, which is freedom under the authority of God. Therefore, to overcome this problem, the researcher applied the Among system. The purpose of this paper is to determine the activeness of student learning in online informatics learning using the Among system. This research is descriptive qualitative research. The results showed that the students' learning activeness having implemented the Among system had increased. The researcher suggests that teachers need to first identify students' existent situations and conditions before implementing the Among system due to its non-suitability in any context.

Keywords: among system, student activeness, online learning

ABSTRAK

Keaktifan belajar siswa merupakan hal yang sangat penting dalam proses pembelajaran. Namun, keaktifan belajar siswa masih menjadi sebuah permasalahan di sekolah. Siswa yang diobservasi oleh peneliti saat menjalani program praktek lapangan memiliki keaktifan yang rendah. Berdasarkan hasil total persentase lembar observasi keaktifan belajar siswa yaitu sebesar 37% tergolong pada kategori

kurang aktif. Pada dasarnya sikap keaktifan belajar siswa dipengaruhi oleh pendekatan yang digunakan oleh guru dalam pembelajaran. Pendekatan pembelajaran dengan sistem among memberikan kebebasan maupun ruang bagi siswa untuk terlibat aktif dalam pembelajaran. Kebebasan yang ada tentunya tidak menyimpang dari pemahaman yang benar menurut perspektif Kristen, yaitu kebebasan yang tetap berada di bawah otoritas Allah. Oleh karena itu untuk mengatasi permasalahan ini peneliti menerapkan sistem among. Tujuan penulisan paper ini yaitu untuk mengetahui keaktifan belajar siswa pada pembelajaran informatika yang dilakukan secara daring dengan menggunakan sistem among. Penelitian ini merupakan penelitian kualitatif deskriptif. Hasil penelitian menunjukkan bahwa keaktifan belajar siswa setelah penerapan sistem among mengalami peningkatan. Saran yang diberikan oleh peneliti sebelum menerapkan sistem among guru perlu terlebih dahulu mengidentifikasi situasi dan kondisi yang ada pada siswa. Sebab tidak semua permasalahan yang ada di dalam kelas dapat terselesaikan dengan menerapkan sistem among.

Kata Kunci: sistem among, keaktifan belajar siswa, pembelajaran daring

PENDAHULUAN

Mutu pendidikan dapat terlihat melalui proses pembelajaran yang terjadi di dalamnya. Hal ini menunjukkan pentingnya keberhasilan dari suatu pembelajaran. Keberhasilan suatu pembelajaran dapat dilihat berdasarkan pencapaian siswa terhadap kompetensi belajar yang terdiri dari proses dan hasil belajar. Keberhasilan suatu pembelajaran dalam hal proses belajar ditentukan oleh keaktifan belajar siswa ataupun keterlibatan siswa, sehingga keaktifan belajar menjadi hal yang penting dalam proses pembelajaran (Mulyasa dalam Wibowo, 2016; Sihaloho et al., 2020). Keterlibatan aktif (keaktifan) ini mencakup: mencatat penjelasan yang diberikan oleh guru, mengerjakan tugas, berpartisipasi, menghargai pendapat orang lain, menerima tanggungjawab, bertanya kepadapengajar atau teman, dan meresponi pertanyaan (Wibowo, 2016).

Namun, keaktifan belajar siswa di sekolah masih menjadi sebuah permasalahan. Berdasarkan hasil observasi yang dilakukan oleh peneliti pada mata pelajaran informatika di kelas VIII A ditemukan permasalahan tentang rendahnya keaktifan belajar siswa. Hal ini terlihat dari fakta-fakta yang terjadi di kelas VIII A. Dari 19 orang siswa yang hadir dalam proses pembelajaran, tidak ada satupun siswa yang meresponi pertanyaan guru. Kejadian seperti ini sering terjadi selama proses pembelajaran. Selain itu, terlihat juga bahwa tidak terdapat satupun siswa yang bertanya kepada guru terkait materi pembelajaran. Selama proses berdiskusi siswa kelas VIII A juga terlihat pasif dan tidak berani mengungkapkan pendapatnya. Sehingga tidak terjadi komunikasi yang interaktif antara guru dengan siswa maupun siswa dengan siswa. Pada akhir pembelajaran, peneliti melihat bahwa siswa kelas VIII A tidak mencatat penjelasan yang diberikan guru. Berdasarkan fakta-fakta di atas, dapat disimpulkan bahwa terdapat permasalahan

mengenai rendahnya keaktifan belajar siswa kelas VIII A.

Pada dasarnya dalam aktivitas pembelajaran, keaktifan belajar siswa dapat dipengaruhi oleh kondisi yang direncanakan guru. Menurut Masruroh (2017) untuk meningkatkan keaktifan belajar siswa, guru harus berperan sebagai fasilitator selama prosespembelajaran. Peran sebagai fasilitator memiliki arti guru hanya mendampingi dan mengarahkan proses pembelajaran yang membawa siswa untuk berpikir, serta menggali suatu pengetahuan secara mandiri. Terdapat faktor yang dapat mempengaruhi keaktifan belajar siswa selama proses pembelajaran, salah satunya faktor pendekatan belajar *(approach to learning)* yang di dalamnya termasuk strategi ataupun cara yang dapat menunjang keefektifan dan efisiensi proses pembelajaran (Anggraeni & Wasitohadi, 2014). Rizkyana (2013) mengungkapkan bahwa, untuk bisa meningkatkan keaktifan belajar siswa guru perlu menerapkan pendekatan belajar yang menciptakan suasana kelas menjadi lebih hidup, komunikatif, aktif, dan mengajak siswa untuk berpartisipasi dalam pembelajaran. Bilamelihat permasalahan yang terjadi di dalam kelas VIII A, terlihat bahwa suasana kelas memang cenderung pasif dan tidak memberikan ruang bagi siswa untuk bisa berpartisipasi dalam proses pembelajaran. Sehingga diperlukan sebuah pendekatan pembelajaran yang mampu menciptakan suasana kelas lebih hidup, interaktif, dan memberikan ruang untuk siswa.

Peneliti melihat bahwa sistem among yang disampaikan oleh Ki Hajar Dewantara bisa menjadi solusi atas permasalahan keaktifan belajar siswa di kelas VIII A. Menurut Zulfiati (2018) prinsip dasar dari sistem among yaitu menempatkan siswa sebagai sentral pada proses pendidikan, sehingga dalam penerapannya siswa diberikan kebebasan untuk menjadi manusia yang merdeka hatinya, merdeka pikirannya, dan merdeka tenaganya. Kebebasan siswa yang di maksud dalam sistem among salah satunya yaitu siswa diberikan kebebasan untuk dapat berdiskusi dan berpartisipasi selama proses pembelajaran. Hal ini tentunya akan menciptakan suasana pembelajaran yang lebih hidup dan interaktif. Dalam penerapan sistem among guru memiliki peran untuk membimbing siswa agar bisa mencari pengetahuannya sendiri. Sistem among juga memiliki kelebihan yang tidak dimiliki oleh sistem pembelajaran lain, yaitu sistem ini lahir dari kebudayaan dan kepribadian bangsa Indonesia. Sehingga sistem ini sudah sangat melekat dan sesuai dengan kebutuhan yang adadi dalam sistem pendidikan Indonesia.

Pada dasarnya gagasan pendidikan yang memerdekakan dibangun atas dasar kepercayaan Ki Hajar melihat manusia sebagai makhluk yang hidup sesuai dengan kodratnya.Kodrat yang dimaksud ialah segala kekuatan di dalam hidup batin dan hidup lahir dari anak- anak itu sendiri, itulah yang dinamakan kekuatan kodrat (Dewantara, 2011). Kekuatan kodratyang dimaksud oleh Ki Hajar dalam hal ini adalah natur manusia

itu sendiri, yaitu seorang ciptaan yang memiliki kehendak bebas (kemampuan dalam memilih). Berdasarkan perspektif Kristen, gagasan pendidikan yang memerdekakan tentunya perlu dikembalikan kepada pemahaman yang benar. Frame (1987) mengatakan bahwa, sebagai seorang ciptaan tentunyamanusia memiliki keterbatasan dalam segala aspek kehidupan. Keterbatasan ini menjadikan manusia sebagai makhluk yang memiliki ketergantungan dengan Allah (Tarigan, 2019). Oleh karena itu, manusia perlu menyadari bahwa kekuatan kodrat harus dilandasi pada kebenaranAllah. Allah adalah satu-satunya yang empunya kehidupan manusia.

Beberapa peneliti terdahulu sudah menggunakan sistem among untuk mengatasi berbagai permasalahan yang terjadi di dalam kelas (Alfansuri & Harini, 2016; Zulfiati, 2018). Akan tetapi, belum banyak penelitian yang menggunakan sistem among untuk meningkatkan keaktifan belajar siswa terkhusus pada proses pembelajaran yang bersifat daring. Sehinggga peneliti tertarik untuk menerapkan sistem among dalam menjawab permasalahan terkait keaktifan belajar siswa kelas VIII A. Adapun rumusan masalah dalam penelitian ini, yaitu; Bagaimanakah keaktifan belajar siswa yang diajar dengan menggunakan sistem among? Adapun tujuan penelitian ini yaitu untuk mengetahui keaktifan belajar siswa pada pembelajaran informatika yang dilakukan secara daring dengan menggunakan sistem among. Hasil dari penelitian ini diharapkan dapat bermanfaat bagi dunia pendidikan Indonesia, serta memberikan inspirasi untuk penelitian yang berkaitan dengan implementasipemikiran dari Ki Hajar Dewantara.

TINJAUAN LITERATUR

Keaktifan Belajar Siswa

Keaktifan belajar siswa merupakan kegiatan dalam proses pembelajaran yang meliputi kegiatan fisik maupun non fisik, yaitu berfikir dan bertindak sebagai suatu rangkaian yang tidak dapat dipisahkan (Wibowo, 2016; Nugraha, 2019). Yunita & Wijayanti (2017) mengatakan ketika siswa melakukan kegiatan di kelas bersama dengan guru selama pembelajaran berlangsung itu yang disebut keaktifan belajar siswa. Oleh karena itu, dapat disimpulkan bahwa keaktifan belajar siswa merupakan aktivitas yang dilakukan siswa dalam proses pembelajaran baik secara fisik maupun non fisik yang mendukung jalannya proses pembelajaran.

Terdapat beragam cara yang dapat dilakukan guru dalam melihat keaktifan belajar siswa yakni melalui indikator keaktifan belajar siswa, sebagai berikut; (1) siswa mencatat materi yang dijelaskan oleh guru, (2) siswa bertanya kepada guru terkait materi pembelajaran, (3) siswa menjawab pertanyaan yang diberikan guru, (4) siswa aktif dalam berdiskusi, (5) siswa berani dalam mengemukakan pendapat (Dewi et.al., 2016; Kharis, 2019;Sumiatie, 2017). Keaktifan belajar siswa di kelas dipengaruhi oleh 2 faktor yaitu faktor

internalyang berasal dari dalam diri siswa dan faktor eksternal yang berasal dari luar (Kosasih, 2017; Ratnawati & Marimin, 2014). Faktor internal mencakup aspek fisiologis dan psikologis, misalnya kemampuan kognitif siswa. Sedangkan faktor eksternal mencakup faktor lingkungandan faktor instrumental seperti strategi ataupun sistem yang digunakan oleh guru, kurikulum, dan media pembelajaran.

Berdasarkan faktor-faktor tersebut tentunya terdapat faktor yang bisa dilakukan gurudalam meningkatkan keaktifan belajar siswa. Seperti yang disampaikan oleh Gagne dan Briggsdalam Kurniawati (2012) mengatakan bahwa terdapat faktor-faktor yang dapat dilakukan oleh guru untuk menumbuhkan keaktifan belajar siswa selama proses pembelajaran, yaitu:

(1) Memberikan motivasi atau menarik perhatian siswa, (2) Menjelaskan tujuan instruksional(kemampuan dasar kepada peserta didik), (3) Mengingatkan kompetensi belajar kepada peserta didik, (4) Memberikan stimulus (masalah, topik, dan konsep), (5) Memberi petunjuk kepada peserta didik cara mempelajarinya, (6) Memunculkan aktivitas dan partisipasi pesertadidik dalam kegiatan pembelajaran, (7) Memberi umpan balik (*feed back*) 8) Melakukan tagihan-tagihan terhadap peserta didik peserta didik berupa tes dan sebagainya. 9) Menyimpulkan setiap materi yang disampaikan diakhir pelajaran.

Pada pembelajaran daring, tentunya terdapat perbedaan dalam melihat keaktifan belajar siswa selama proses pembelajaran. Sebab interaksi yang terjadi dalam pembelajaran dari terbagi menjadi 2 yaitu *Synchronous* dan *Asynchronous*. Menurut Suranto (2009) *synchronous* merupakan komunikasi secara langsung melalui *video conference* dengan menggunakan platform online (Microsoft Teams, Zoom, dan yang lainnya). Sedangkan, *Asynchronous* tidak melalui *video conference* tetapi guru memberikan tugas kepada siswa pada saat jam pembelajaran. Keaktifan belajar siswa bisa terlihat pada komunikasi *synchronous* ketika siswa mencatat penjelasan guru, bertanya kepada guru, menjawab pertanyaan guru, aktif berdiskusi, dan berani mengungkapkan pendapatnya. Sedangkan, dalam komunikasi yang bersifat *Asynchronous* keaktifan belajar siswa terlihat dari bertanya kepada guru terkait materi, mampu menyelesaikan masalah, dan aktif meresponi pertanyaanguru.

Sistem Among

Menurut Yanuarti (2018) sistem among dapat diartikan sebagai pemeliharaan dengan memberi ruang ataupun kebebasan kepada siswa untuk bergerak menurut kemauannya. Zulfiati (2018) mengemukakan bahwa sistem among merupakan sebuah gagasan yang menempatkan siswa sebagai sentral dalam pendidikan dan guru (pamong) sebagai pembimbing yang membimbing siswa dalam mencari pengetahuannya. Berdasarkan haltersebut, dapat dikatakan bahwa sistem among merupakan cara yang

mengedepankan pemberian ruang ataupun kebebasan kepada siswa untuk dapat bergerak dengan pilihannya sendiri, namun guru (pamong) tetap berperan sebagai pembimbing bagi siswa.

Wangid (2009) mengemukakan bahwa terdapat 2 prinsip dasar dalam sistem among, yakni: (1) kodrat alam sebagai syarat untuk menghidupkan dan mencapai kemajuan dengan cepat, (2) kemerdekaan sebagai syarat untuk menghidupkan serta menggerakkan kekuatan lahir dan batin siswa agar dapat hidup mandiri. Selain prinsip, sistem among juga memiliki sebuah pedoman yaitu Trilogi Kepemimpinan yang meliputi: *Ing ngarsa sung tuladha, Ing madya mangun karsa,* dan *Tut wuri Handayani* (Tanaka, 2018). Soeratman (1985) memaparkan pedoman trilogi kepemimpinan. *Ing ngarsa sung tuladha* berarti guru (pamong)sebagai pemimpin harus mampu memberikan teladan yang baik untuk siswanya. *Ing madya mangun karsa* berarti guru harus mampu membangkitkan sikap berswakarsa (kemauan) danberkreasi dalam diri siswa. *Tut wuri handayani* berarti seorang guru harus mampu menjadi pembimbing yang mengarahkan siswa untuk bisa bertanggung jawab dengan dirinya sendiri.Pada dasarnya baik prinsip maupun pedoman saling berikatan satu sama lain. Prinsip sistem among tidak dapat di implementasikan tanpa adanya sebuah pedoman, begitu pula sebaliknya pedoman tidak akan berjalan tanpa sebuah prinsip.

Pada penerapan sistem among juga menekankan penyampaian materi harus menyenangkan (tidak membosankan), serta contoh yang diberikan harus bisa diambil dari kehidupan sehari-hari (kontekstual) (Mujiono, 2019). Bila dilihat secara sekilas sistem amongmirip dengan pendekatan pembelajaran kontekstual, dimana setiap materi yang diberikan oleh guru harus bisa dikaitkan dengan kehidupan sehari-hari karena hal itu dinilai lebih bermakna untuk siswa. Sistem among memiliki pendekatannya sendiri yaitu pendekatan pembelajaran merdeka. Menurut Dewantara dalam Hendri (2020) pembelajaran merdeka merupakan sebuah pendekatan dalam mengajak siswa untuk mencari segala pengetahuan melalui pikirannya sendiri, bukan berdasarkan buah pemikiran orang lain.

Bila dilihat secara umum, terdapat beberapa tahapan dalam proses pembelajaran yaitu kegiatan awal pembelajaran (pembukaan), kegiatan inti pembelajaran dan kegiatan akhir pembelajaran (penutup) (Herawati, 2018; Rooijakkers, 2008). Sedangkan, pada penerapan sistem among terdiri dari 5 fase yaitu fase pendahuluan, fase penciptaan atmosfir merdeka, fase among, fase pertanggungjawaban, dan fase penutup (Rahayu 2017). Setiap fase yang ada pada sistem among memiliki keunikan tersendiri yaitu dalam penerapannya terdapat falsafah-falsafah maupun asas yang dilakukan oleh guru.Mujiono (2019) mengemukakan beberapa falsafah maupun asas yang digunakan dalampenerapan

sistem among, sebagai berikut: falsafah Tri Nga (*Ngerti, Ngroso, Nglakoni*), falsafah 3N (*Niteni, Nirokke, Nambahi*), dan asas kekeluargaan. Hal ini juga yang menjadikan sistem among berbeda dengan strategi ataupun metode pembelajaran yang lain.

Keterkaitan Sistem Among dengan Keaktifan Belajar Siswa

Pada dasarnya penerapan sistem among tidak terlepas dari prinsip yang ada pada sistemamong. Menurut Soenarno (2005) sistem among mengandung prinsip bahwa siswa merupakan objek sekaligus subjek dalam pembelajaran, sehingga baik guru (pamong) maupun siswa harussama-sama aktif. Pandangan siswa sebagai objek sekaligus subjek memiliki pengertian bahwa dalam proses pembelajaran guru (pamong) harus bisa menciptakan aktivitas kelas yang berpusat kepada siswa (Wijayanti & Praheto, 2020). Seperti misalnya, memberikan ruang untuk siswa bisa berdiskusi dan mengajak siswa untuk terlibat langsung dalam proses pembelajaran. Bila ditinjau lebih dalam prinsip sistem among tentunya selaras dengan hakikatkeaktifan itu sendiri. Keadaan ketika siswa tidak hanya mendengarkan, mengamati, danmengikuti penjelasan yang diberikan oleh guru, melainkan terlibat langsung dalam melaksanakan suatu percobaan ataupun peragaan itulah yang disebut keaktifan belajar siswa (Kurniawati, 2017).

Pada dasarnya setiap falsafah maupun asas yang terdapat pada sistem among tentunya mempengaruhi sikap keaktifan belajar siswa selama proses pembelajaran. Berikut penjelasan dari setiap falsafah maupun asas yang terdapat dalam sistem among dan keterkaitannya dengankeaktifan belajar siswa.

Falsafah Tri Nga (*Ngerti, Ngroso, Nglakoni*). Menurut (Widyarini & Istiqomah, 2018) falsafah Tri Nga memiliki arti bahwa pada proses pembelajaran siswa tidak cukup hanyasekedar tahu ataupun paham suatu materi, melainkan siswa perlu merasakan serta menyadari, kemudian mengaplikasikan setiap pembelajaran yang diterima dalam kehidupan sehari-hari. Falsafah Tri Nga selaras dengan konsep aspek kognitif (*ngerti*), afektif (*ngroso*), dan psikomotor (*nglakoni*). Bila ditinjau lebih dalam, falsafah Tri Nga tentunya mengajak siswa untuk dapat berperan selama proses pembelajaran. Sebab siswa diajarkan untuk tidak hanya memahami materi pembelajaran, melainkan mengaplikasikan materi pembelajaran tersebut. Dalam hal ini secara tidak langsung sikap keaktifan yang ada di dalam diri siswa akan berkembang, sebab siswa akan bersikap aktif dalam mencari tahu cara untuk dapat mengaplikasikan pembelajaran yang diterimanya.

Falsafah 3N (*niteni, nirokke, nambahi*). Menurut Rahayu, Istiqomah, Purnami, & Agustio (2017) *Niteni* berasal dari kata dasar "*titen*" yang menunjuk pada kemampuan untuk mengenali dan menangkap makna (sifat, ciri, prosedur, kebenaran) dari suatu obyek. Sedangkan, *Nirokke* dan *Nambahi* dapat diterjemahkan sebagai meniru (*to*

imitate) dan mengembangkan/menambah (*to innovate/to add value*). Pembahasan kedua konsep ini disatukan mengingat *Nirokke* dan *Nambahi* berada dalam tataran yang sama yaitu aplikasi perolehan proses *Niteni*. Perbedaan diantara keduanya terletak pada kadar dan proses kreatifnya. Pada dasarnya sebagian besar kemampuan, keterampilan dan perilaku siswa adalahhasil proses peniruan, misalnya berbicara, berperilaku, dan sebagainya. Pada proses *Nambahi* atau menambahkan/mengembangkan adalah proses lanjutan dari "Nirokke". Pada proses ini siswa dituntut untuk bisa lebih kreatif dan inovatif dalam proses pembelajaran. Sehingga siswatidak hanya mendengarkan penjelasan guru, melainkan siswa mengembangkan dari apa yang sudah dijelaskan oleh guru

Asas kekeluargaan. Pada asas kekeluargaan siswa dididik untuk bisa saling memberikan kontribusi dan memiliki tanggungjawab sebagai bagian dari anggota keluarga. Asas kekeluargaan dalam proses pembelajaran diterapkan melalui diskusi di dalam kelompok. Adapun tujuan dari pembentukan kelompok agar setiap siswa dapat memberikan kontribusinya untuk kelompok dengan berlandaskan asas kekeluargaan (Nurutami, 2015). Kontribusi yang diberikan siswa bisa berupa aktif dalam berdiskusi untuk menyelesaikan masalah, berani mengungkapkan pendapatnya, dan sebagainya. Penerapan asas kekeluargaan tentunya akan melatih siswa untuk bisa berpartisipasi aktif dalam proses pembelajaran, sebab setiap siswa bertanggungjawab terhadap kelompoknya masing-masing.

Secara keseluruhan mulai dari prinsip, falsafah, maupun asas yang ada di dalam sistemamong semuanya sangat sesuai dengan hakikat keaktifan belajar siswa. Sehingga sistem among dinilai mampu untuk meningkatkan keaktifan belajar selama proses pembelajaran. Selain diterapkan untuk mengatasi permasalahan keaktifan belajar, sistem among juga diterapkan dalam hal meningkatkan motivasi dan hasil belajar siswa serta pengelolaan kelas. Seperti penelitian yang dilakukan oleh Alfansuri & Harini (2016) yang mengangkat topik penerapan sistem among untuk meningkatkan motivasi dan hasil belajar siswa.

METODE PENELITIAN

Teknik analisis data yang digunakan pada penelitian ini yaitu kualitatif deskriptif dikarenakan paper ini bertujuan untuk mengetahui keaktifan belajar siswa melalui penerapan sistem among. Penelitian ini berlangsung selama enam minggu dengan melakukan observasi dan mengajar. Data keaktifan belajar siswa sebelum penerapan sistem among diambil saat observasi dan setelah penerapan sistem among diambil ketika mengajar.

Partisipan

Subjek penelitian ini adalah siswa kelas VIII A sebanyak 19 orang pada suatu sekolah di Sangihe. Pemilihan subjek penelitian dilakukan secara *purposive sampling* yang sesuai dengan konteks pada masa program praktik lapangan dan tujuan dari penelitian.

Pengumpulan Data

Peneliti menggunakan lembar observasi keaktifan belajar siswa sebagai sumber data utama. Observasi dilakukan dengan memberikan ceklis (skor 3) pada siswa yang menunjukkantindakan yang sesuai indikator, ceklis (skor 2) pada siswa yang menunjukkan tindakan yang kurang sesuai dengan indikator, dan ceklis (skor 1) pada siswa yang tidak melakukan tindakan sesuai indikator keaktifan belajar siswa. Data yang diperoleh dari lembar observasi keaktifanmerupakan data keterlaksanaan ketika melakukan observasi guru mentor dan pada saat pembelajaran yang dilakukan oleh peneliti. Kehadiran peneliti sebagai instrumen utama. Sari& Rahardi (2013) mengungkapkan bahwa peneliti sebagai instrumen utama memiliki arti yaitupeneliti sebagai perancang, pelaksana, pengumpul data, penganalisis data, penafsir data hingga pelapor hasil. Untuk data setelah penerapan sistem among menggunakan lembar umpan balik mentor dan refleksi mengajar.

Analisis Data

Seluruh data dianalisis secara deskriptif dengan mendeskripsikan hasil yang diperoleh dengan statistik deskriptif dan narasi. Wijayanti dalam Suseno, Yuwono, & Muhsetyo (2017) mengatakan keaktifan belajar siswa dapat dinilai melalui lembar observasi keaktifan belajar yang berisi indikator-indikator keaktifan yang harus dicapai, dengan menghitung setiap persentase indikator keaktifan tersebut berdasarkan rumus berikut:

$$\text{Capaian indikator} = \frac{\text{Jumlah skor yang diperoleh}}{\text{Skor maksimum setiap indikator}} \times 100\%$$

Adapun hasil dari capaian indikator akan menentukan bagaimana kategori keaktifan belajarsiswa seperti yang disampaikan oleh Arikunto dalam Alimuddin (2017), sebagai berikut:

Tabel 1. Kategori Keaktifan Siswa

Rentang Persentase Hasil Keaktifan (%)	Kategori
P > 80	Sangat Aktif
60 < P ≤ 80	Aktif
40 < P ≤ 60	Cukup
20 < P ≤ 40	Kurang
P < 20	Sangat Kurang

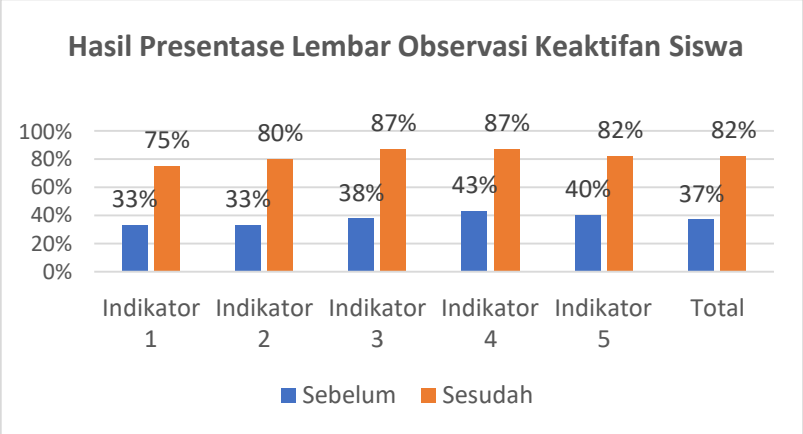
Data dari lembar umpan balik mentor dianalisis secara narasi. Sedangkan, data dari refleksi mengajar dibuat secara *coding* sesuai dengan fase yang terdapat dalam sistem among.

HASIL PENELITIAN

Berikut pemaparan hasil keaktifan belajar siswa sebelum dan sesudah penerapan sistem among, serta hasil penerapan sistem among di dalam proses pembelajaran.

Keaktifan Belajar Siswa dalam Pembelajaran

Berikut hasil persentase lembar observasi keaktifan belajar siswa sebelum dan sesudah penerapan sistem among.



Gambar 1. Persentasi Keaktifan Siswa Sebelum dan Sesudah Penerapan Sistem Among

Keaktifan Belajar Siswa Sebelum Penerapan Sistem Among

Berdasarkan pemaparan data tersebut, terlihat bahwa hasil rata-rata keaktifan belajarsiswa sebelum penerapan sistem among pada indikator pertama 33%, indikator kedua 33%, indikator ketiga 38%, indikator keempat 43%, dan indikator kelima 40%. Berdasarkan data tersebut, terdapat 4 indikator yang tergolong dalam kategori kurang

aktif yaitu indikator pertama, kedua, ketiga, dan kelima. Sedangkan, indikator keempat tergolong pada kategori cukup aktif. Berdasarkan hasil rata-rata keseluruhan indikator terlihat bahwa persentase sebesar 37%, artinya secara keseluruhan siswa masih tergolong dalam kategori kurang aktif.

Keaktifan Belajar Siswa Sesudah Penerapan Sistem Among

Berdasarkan pemaparan data tersebut, terlihat bahwa hasil rata-rata keaktifan belajarsiswa sebelum penerapan sistem among pada indikator pertama 75%, indikator kedua 80%, indikator ketiga 87%, indikator keempat 87%, dan indikator kelima 82%. Berdasarkan data tersebut, terdapat 2 indikator yang tergolong kategori aktif yaitu indikator pertama dan kedua. Sedangkan, indikator ketiga, keempat, dan kelima masuk dalam kategori sangat aktif. Berdasarkan hasil rata-rata keseluruhan indikator terlihat bahwa persentase sebesar 82%, artinya secara keseluruhan siswa sudah tergolong kategori sangat aktif.

Perbandingan Keaktifan Siswa Sebelum dan Sesudah Penerapan Sistem Among

Menurut Dewi (2016) yang juga melakukan penelitian keaktifan belajar siswa denganmenggunakan lembar observasi keaktifan, peneliti perlu melakukan perhitungan peningkatanpada setiap indikator yang ditentukan. Oleh karena itu, berikut perbandingan data keaktifan belajar siswa sebelum dan sesudah penerapan sistem among beserta perhitungan persentasepeningkatannya. *Indikator pertama*. Sebelum penerapan sistem among sebesar 33% dan sesudah 75%. Terjadi peningkatan sebesar 42%. *Indikator kedua.* Sebelum penerapan sistemamong sebesar 33% dan sesudah 80%. Terjadi peningkatan sebesar 47%. *Indikator ketiga.* Sebelum penerapan sistem among sebesar 38% dan sesudah 87%. Terjadi peningkatansebesar 49%. *Indikator empat.* Sebelum penerapan sistem among sebesar 43% dan sesudah 87%. Terjadi peningkatan sebesar 44%. *Indikator kelima.* Sebelum penerapan sistem among sebesar 40% dan sesudah 82%. Terjadi peningkatan sebesar 42%. Selain kelima indikator, terdapat juga data total keseluruhan indikator sebelum dan sesudah penerapan sistem among. Bila dilihat pada grafik terjadi peningkatan sebesar 45%, dari yang semula 37% menjadi 82%. Secara keseluruhan, hasil persentase setiap indikator maupun total keseluruhan indikator mengalami peningkatan.

Implementasi Sistem Among Dalam Pembelajaran

Berikut pembahasan setiap fase yang terdapat pada penerapan sistem among yang meliputi fase pendahuluan, fase penciptaan atmosfer merdeka, fase among, fase pertanggungjawaban, dan fase penutup.

Fase pendahuluan. Mujiono (2019) mengatakan bahwa pada fase pendahuluan tindakan yang perlu dilakukan guru yaitu menyampaikan tujuan pembelajaran serta motivasikepada siswa. Atas dasar ini, peneliti melaksanakan setiap tindakan yang terdapat dalam fase pendahuluan yang mencakup menarik perhatian siswa sebelum memulai pembelajaran, menyampaikan tujuan pembelajaran, memotivasi siswa, dan melakukan review pembelajaran. Selain itu, pada fase ini peneliti mencoba membangun relasi dengan siswa dengan cara memberikan ruang diskusi apabila ada hal yang tidak disukai oleh siswa. Tindakantersebut merupakan prinsip dasar dari penerapan sistem among yaitu memberikan kebebasan kepada siswa untuk dapat bertindak sesuai kodratnya. Setiap tindakan yang terjadipada fase pendahuluan dapat terlaksana dengan baik. Hal ini terlihat melalui respon yang diberikan siswa ketika peneliti baru memulai proses pembelajaran. Setiap siswa tertarik dalam mengikuti pembelajaran yang diberikan oleh peneliti. Hal ini diperkuat dengan pemberian poin maksimal yang diberikan oleh guru mentor pada lembar umpan balik, terkhusus pada aspek penilaian menarik perhatian siswa sebelum mengajar. Melalui hal ini dapat terlihat bahwa fase pendahuluan sudah terlaksana dengan benar.

Fase penciptaan atmosfer merdeka. Pada fase ini peneliti menerapkan falsafah *Ing ngarsa sung tuladha* melalui penjelasan terkait materi pembelajaran, falsafah *Ing madya mangun karsa* melalui pemberian semangat dan motivasi kepada siswa, dan aspek kekeluargaan dengan membagi siswa ke dalam kelompok (Mujiono, 2019). Pada fase ini peneliti kembali membuka ruang diskusi kepada siswa apabila terdapat siswa yang keberatandengan pembagian kelompok yang dilakukan oleh peneliti. Pemberian ruang diskusi yang diberikan oleh peneliti dibarengi dengan pemberian pemahaman yang benar kepada siswa terkait tujuan dari pembentukan kelompok. Sehingga setiap siswa dapat memahami hal tersebut. Setiap tindakan yang terjadi pada fase ini dapat terlaksana dengan baik, terkhusus pada penerapan asas kekeluargaan. Berdasarkan hasil pengamatan yang dilakukan peneliti pada setiap kelompok, terlihat bahwa siswa kelas VIII A menjadi lebih aktif dalam berdiskusi

dan berani mengungkapkan pendapatnya di dalam kelompok. Selain itu, kedua falsafah yangterdapat dalam fase ini juga diterapkan dengan baik oleh peneliti. Hal ini terlihat melalui komentar yang diberikan oleh guru mentor. Atas dasar ini, dapat dikatakan bahwa peneliti sudah menerapkan fase penciptaan atmosfir dengan baik.

Fase among. Pada fase ini peneliti menerapkan falsafah *Tut Wuri Handayani* dengan memberikan bimbingan kepada siswa di dalam kelompok. Hal ini selaras dengan yang disampaikan oleh Nugrahaningsih (2011) mengatakan bahwa di dalam fase among harus terdapat penerapan *Tut Wuri Handayani* yaitu memberikan bimbingan kepada

siswa baik secara individu maupun kelompok. Hal selaras yang disampaikan oleh Wardhana, S, & Pratiwi(2020) pada penerapan *Tut Wuri Handayani* guru tidak hanya sekedar membimbing, melainkan memberikan dorongan kepada siswa untuk terus maju. Peneliti melakukan bimbingan kepada setiap kelompok secara bergantian dan memberikan dorongan berupa kata-kata penguatan kepada siswa. Terlihat bahwa bimbingan yang diberikan peneliti juga berpengaruh terhadap keaktifan belajar siswa di dalam kelompok. Hal ini juga diperkuat dengan komentar yang diberikan guru mentor yang berbunyi "*penerapan falsafah ing ngarsosung tulodho yang dilakukan pak Yohanes sangat membantu peserta didik dalam pembelajaran online*". Melalui hal ini dapat dikatakan bahwa peneliti sudah menerapkan faseamong dengan baik.

Fase pertanggungjawaban. Pada fase ini peneliti meminta kepada siswa untuk mempresentasikan hasil diskusi kelompok dengan memastikan setiap anggota kelompok memahami hal yang akan disampaikan. Bagi kelompok yang tidak sedang melakukan presentasi, peneliti memberi instruksi untuk dapat memberikan tanggapan maupun pertanyaan terkait presentasi tersebut. Hal ini bertujuan agar setiap siswa memiliki keberanian untuk mengemukakan pendapatnya. Pada fase ini terlihat bahwa setiap siswa sudah berusaha untuk memberikan yang terbaik dalam melakukan presentasi, meskipun terdapat siswa yang cenderung mendominasi. Pada akhir pembelajaran peneliti juga lebih menekankan fungsi serta tujuan dari pembentukan kelompok. Hal ini perlu dipahami oleh siswa, sebab hal ini harus sesuai dengan asas kekeluargaan dalam sistem among yang mengedepankan sikap gotong-royong untuk mencapai tujuan bersama. Hal selaras yang disampaikan oleh Murni (2016) bahwa melalui pembentukan kelompok siswa harus saling memberikan kontribusi guna mencapai tujuan yang sudah ditentukan sebelumnya. Secara keseluruhan, dapat dikatakan peneliti sudah menerapkan fase ini dengan baik.

Fase penutup. Pada fase ini peneliti bersama dengan siswa saling menyimpulkan hasilpembelajaran dan pemberian tugas. Selain itu, peneliti juga mengajak siswa untuk kembali mengingat pelajaran yang sudah didapat serta relevansinya dalam kehidupan sehari-hari. Hal ini penting sebab pembelajaran yang dapat dihubungkan dengan kehidupan sehari-hari dinilai lebih bermakna (Rukajat, 2018). Berdasarkan komentar serta penilaian yang diberikan oleh

guru mentor pada lembar umpan balik, terlihat bahwa peneliti sudah menerapkan sebagian dari fase penutup dengan baik. Hal yang tidak dilakukan peneliti pada fase ini yaitu pemberianpekerjaan rumah (PR) kepada siswa. Padahal pemberian tugas rumah merupakan hal yang penting untuk menguatkan kembali pemahaman siswa terhadap materi pembelajaran (Darminto, 2012).

PEMBAHASAN

Hasil observasi dari penelitian ini menunjukkan bahwa keaktifan belajar siswa kelas VIII A masih tergolong rendah. Padahal sikap keaktifan belajar siswa menjadi hal yang pentingdalam sebuah pembelajaran. Sebab keaktifan belajar siswa dapat menentukan keberhasilan dari sebuah pembelajaran. Pada dasarnya sikap keaktifan belajar siswa dipengaruhi oleh 2 faktor yaitu internal dan eksternal. Faktor internal berasal dari dalam siswa itu sendiri, sedangkan faktor eksternal berasal dari luar. Dalam hal ini, pemberian strategi/metode yang dilakukan oleh guru masuk ke dalam faktor eksternal. Artinya, pemberian strategi/metode yang diterapkan oleh guru dapat mempengaruhi keaktifan belajar siswa selama proses pembelajaran.

Berdasarkan hal tersebut faktor pemberian strategi maupun metode menjadi hal yang penting. Bila melihat permasalahan yang terjadi pada siswa kelas VIII A yaitu kurangnya pemberian ruang kepada siswa selama proses pembelajaran. Hal ini tentunya akan mempengaruhi keaktifan siswa, sebab siswa tidak terlibat langsung dalam proses pembelajaran. Atas dari ini penerapan sistem among menjadi solusi yang tepat untuk mengatasi permasalahan keaktifan belajar siswa kelas VIII A. Melalui fase-fase yang terdapat dalam tahap penerapan sistem among, siswa diajak untuk bisa memberikan kontribusinya selama proses pembelajaran (Mujiono, 2019). Berdasarkan hasil persentase lembar observasikeaktifan, terlihat bahwa setiap indikator mengalami peningkatan. Hal ini tentunya memberikan gambaran bahwa penerapan sistem among cukup efektif dalam meningkatkan keaktifan belajar siswa pada proses pembelajaran. Berikut pembahasan dan analisis berdasarkan penerapan sistem among.

Berdasarkan grafik, terlihat bahwa terjadi peningkatan hasil rata-rata dari keseluruhanindikator sebelum dan sesudah penerapan sistem among yaitu sebesar 45%. Melalui hal ini maka dapat dikatakan bahwa penerapan sistem among sangat efektif dalam meningkatkan keaktifan belajar siswa. Meskipun dalam penerapan sistem among secara daring terdapat banyak tantangan yang harus dilalui peneliti, namun tidak mengurangi kebenaran dari hasil yang telah dipaparkan oleh peneliti.

Pada dasarnya sistem among berkaitan dengan pendekatan pembelajaran merdeka. Landasan filosofis dari pendekatan pembelajaran merdeka yaitu memandang manusia sebagai makhluk merdeka, yang hidupnya tidak bergantung kepada orang lain, melainkan bersandar kepada kekuatan sendiri (Dewantara, 2011). Atas dasar filosofis ini maka dalam penerapannya siswa akan diberikan kebebasan dalam proses pembelajaran. Pemberian kebebasan yang diberikan oleh guru tentunya akan memberikan ruang untuk siswa bertindaksesuai dengan kehendaknya. Namun, hal yang perlu diingat bahwa Ki Hajar mengatakan kebebasan yang ada pada siswa itu yaitu tertib dan damai (Suparlan, 2015). Oleh karena itu, siswa perlu memahami dan menyadari kehendak bebas yang ada

di dalam dirinya.

Manusia (siswa) merupakan mahkluk ciptaan Allah yang diciptakan segambar dan serupa dengan-Nya (Bavinck, 2011). Hal ini menunjukkan bahwa manusia merupakan ciptaan Allah yang istimewa dan berharga (Tarigan, 2019). Allah juga menciptakan manusia dengan kehendak bebas (kemampuan untuk memilih) yang ada pada diri siswa (Cornner, 2004). Susanto (2017) mengatakan bahwa sebelum kejatuhan manusia, manusia dengan kehendaknya hanya berfokus untuk melayani Allah dan melakukan segala yang telah ditugaskan Allah kepadanya, tetapi sebaliknya setelah kejatuhan manusia dalam dosa manusia tetap dapat menggunakan kehendak bebasnya namun apapun yang dikehendaki oleh manusia hanya melakukan hal yang jahat. Atas dasar ini, guru Kristen memiliki peran untuk memberikan pemahaman yang benar kepada siswa terkait kehendak bebas yang dimiliki siswa (Priyatna, 2017). Namun, sebelum memberikan pemahaman yang benar kepada siswa guru Kristen harus terlebih dahulu memiliki hubungan dan komitmen pribadi kepada Yesus dan memberikan hidupnya dikuasai oleh Roh Kudus, melalui hubungan pribadi denganYesus dan tuntunan Roh kudus maka guru Kristen dapat melakukan setiap tugas dan tanggungjawabnya (Gultom et al., 2019). Melalui pemberian pemahaman yang dilakukan oleh guru diharapkan siswa mampu menggunakan kehendak bebasnya sesuai dengan apa yang diperintahkan oleh Allah. Kehendak bebas yang dimaksud dalam hal ini mengacu padaperlakuan dari pikiran dan perasaan siswa, serta tingkah laku di dalam kelas untuk bertanggung jawab terhadap dirinya sendiri (Tanyit, 2005).

KESIMPULAN

Berdasarkan hasil penelitian dan pembahasan yang telah diuraikan, maka dapat disimpulkan bahwa implementasi merdeka belajar dengan penerapan sistem among dapat meningkatkan keaktifan belajar siswa yang meliputi: mencatat penjelasan yang diberikan guru, bertanya kepada guru terkait materi pembelajaran, menjawab pertanyaan yang diberikan guru, aktif berdiskusi selama proses pembelajaran, dan berani mengungkapkan pendapatnya. Hal ini ditunjukkan dengan perbedaan hasil persentase keaktifan belajar siswasebelum dan sesudah penerapan sistem among. Hasil persentase menunjukkan bahwa setelah penerapan sistem among terjadi peningkatan, mulai dari perbandingan persentase

dan kategori pada setiap indikator maupun total keseluruhan indikator. Secara keseluruhan, sistem among menjadi salah satu pendekatan yang tidak boleh dilupakan oleh para pendidik. Sebab sistem among menjadi ciri khas dari sistem pendidikan di Indonesia.

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