ISSN: 2717-8587

Journal for the Mathematics Education and Teaching Pratices

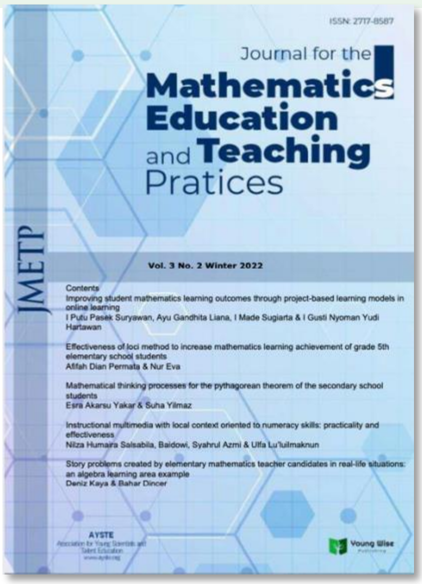
JMETP

Vol. 3 No. 2 Winter 2022

Contents

AYSTE
Association for Young Scientists and Talent Education
www.ayste.org

Young Wise Publishing



Journal for the Mathematics Education and Teaching Practices
e-ISSN: 2717-8587

JMETP

Vol. 3 No. 2 Winter 2022

Journal for the Mathematics Education and Teaching Practices
3(2), December 2022 e-ISSN: 2717-8587

Absracting & Indexing
Index Copernicus, Asos, Google Scholar, Directory of Research Journal Index (DRJI), Research Bible, Acar Index,

Young Wise Publishing/Genç Bilge Yayıncılık
Management-Publicaton Process-Office (Adress 1): 63 – 66 Hatton Garden, Fifth Floor, Suite 23, EC1N 8LE, London, UK
Web site: https://youngwisepub.com/ E-mail: info@youngwisepub.com
ISSN-Ownership-Office (Adress 2): Bahcelievler District 3015 St. No:9/1 Isparta, Turkiye
Web site: http://gencbilgeyayincilik.com/ E-mail: info@gencbilgeyayincilik.com
Note: JMETP supported by Association for Young Scientists and Talent Education (AYSTE) web site: https://ayste.org/ and International Congress on Gifted Youth and Sustainability of the Education (ICGYSE) web site: https://icgyse.net/

youngwisepub.com Young Wise Publishing gencbilgeyayincilik.com

Journal for the Mathematics Education and Teaching Practices

3(2), December 2022 e-ISSN: 2717-8587

Contents

JMETP
Journal for the Mathematics Education and Teaching Practices, 3(2), 57-69, Dec 2022
e-ISSN: 2717-8587
dergipark.org.tr/jmetp

Young Wise Publishing
youngwisepub.com
gencbilgeyayincilik.com © 2022

Research Article

Improving student mathematics learning outcomes through project-based learning models in online learning

I Putu Pasek Suryawan[1]*, Ayu Gandhita Liana[2], I Made Sugiarta[3] and I Gusti Nyoman Yudi Hartawan[4]

Mathematics Education Study Program, Faculty Of Mathematics And Natural Sciences, Universitas Pendidikan Ganesha, Indonesia.

Article Info

Received: 24 July 2022
Accepted: 8 September 2022
Available online: 30 Dec 2022

Keywords:
Project-based learning
Learning outcomes
Google classroom
Video conference

Abstract

This study aims to analyze the effect of project based learning assisted by google classroom and video conference on students' mathematics learning outcomes. This research is a quasi-experimental. Participants of the research, was 148 high school class XI students. The sample selection of the experimental class and the control class used a random sampling technique cluster. The experimental class was 29 people while 29 people were in the control group. Hypothesis testing was carried out using an independent sample t-test with SPSS 22.0 with a significance level. Based on the results of data analysis showed that the average post-test in the experimental class was 74.3 and the control class was 63.1. The results of hypothesis testing produce a probability significance value, meaning that the hypothesis is accepted. The mathematics learning outcomes of class XI high school students who were taught using a project based learning assisted by google classroom and video conference were better than of students who were taught using conventional learning

To cite this article

Surwayan, I.P.P., Liana, A.G., Sugiarta, I.M., & Hartawan, I.G.N.Y., (2022). Improving student mathematics learning outcomes through project-based learning models in online learning. *Journal for the Mathematics Education and Teaching Practices, 3*(2), 57-69.

Introduction

The development of education in the 4.0 revolution era is marked by digital technology in learning activities which makes learning activities take place continuously without space and time limits and the learning process in the current era must be relevant to the era of the industrial revolution 4.0 (Akmal & Santaria, 2020). With the rapid development in this revolutionary era, it is hoped that it will help a lot in the world of education as well (Reflianto & Syamsuar, 2018). However, there are still learning problems in Indonesia, including in mathematics (Izza et al., 2020).

One of the problems of learning mathematics in high school is the lack of learning that encourages students to apply the knowledge learned to solve real-world problems around them that give meaning to themselves (Asmuni, 2020). This is evidenced by the record achievement of the 2019 high school mathematics national exam results which were very low with an average value of 38.60 (Puspendik, 2019). The results of the 2019 national exam are still low, as a reflection of the low mathematics learning outcomes of students in Indonesia. This indicates that there is still a lack of student

[1] Senior Lecturer in Mathematics Education Study Program, Faculty Of Mathematics And Natural Sciences, Universitas Pendidikan Ganesha, Indonesia. E-mail: putu.pasek@undiksha.ac.id ORCID No: 0000 0001 8148 3785
[1] Student in Mathematics Education Study Program, Faculty Of Mathematics And Natural Sciences, Universitas Pendidikan Ganesha, Indonesia E-mail: ayu.gandhita@undiksha.ac.id
[1] Senior Lecturer in Mathematics Education Study Program, Faculty Of Mathematics And Natural Sciences, Universitas Pendidikan Ganesha, Indonesia E-mail: made.sugiarta@undiksha.ac.id
[1] Senior Lecturer in Mathematics Education Study Program, Faculty Of Mathematics And Natural Sciences, Universitas Pendidikan Ganesha, Indonesia E-mail: yudi.hartawan@undiksha.ac.id

learning outcomes. The results of the 2019 national exam are still low, as a reflection of the low mathematics learning outcomes of students in Indonesia. This indicates that there is still a lack of student learning outcomes in the cognitive realm. This, of course, must receive serious attention, especially on cognitive learning outcomes to find solutions for the future (Oktaviana & Prihatin, 2018).

Learning activities are mostly dominated by teachers and giving homework does not accommodate the development of students' abilities in problem solving, reasoning, mathematical connection and communication (Aida et al., 2017). This causes student learning outcomes to be less than optimal because students do not get the opportunity to directly explore their knowledge and only rely on the teacher (Wijaya et al., 2016). In addition, according to Yulia (2020) during online learning students will become more passive to learn, between students and teachers there will be no direct or non-interactive interaction.

In learning mathematics, the selection of the right learning model will affect students' mathematics learning outcomes. This is supported by research by Nasution (2017) which states that student learning outcomes can be improved by using a good learning model, teachers should be able to plan good learning activities by choosing a learning model that fits the material to be delivered to students. This is in line with the results of research conducted by Hasri (2021) which states that the use of certain learning models can have a positive effect on student learning outcomes. The learning model chosen must be in accordance with the characteristics of mathematics learning, namely (1) tiered mathematics learning, (2) following the spiral method, (3) emphasizing deductive thinking patterns, (4) adhering to consistent truth (Mustafa et al., 2021). Learning model which can accommodate all student needs in learning is a *project-based learning* or can be abbreviated PjBL (Andita Putri, 2018) This is because the PjBL model is oriented towards processes and products as a result and provides opportunities for students to work on solving mathematical problems on their own in everyday life (Yutantin, 2018).

According to (Fatma, 2021), the advantages of the PjBL learning model are: (1) improve problem-solving skills, (2) making students more active and successful in solving complex problems, (3) increasing collaboration, (4) providing students with learning experiences and practices in organizing projects, (5) provide learning experiences that involve students in a complex and designed to develop according to the real world. PjBL Model has great potential to contain more interesting and meaningful learning experiences for adult students, such as high school students and college students (Salman et al., 2017).

In a study conducted by (Hasri, 2021) stated that student learning outcomes in the mathematics subject with the PjBL model have increased because students are actively building their own knowledge, but unfortunately this research can only be done in offline learning situations because the application of the PjBL model is not accompanied by learning media that can support online learning. By looking at the online learning situation and the suitability of the PjBL model in overcoming the problem of student learning outcomes, it is necessary to have learning media that will support the implementation of the PBL model syntax in online learning (Salsabila et al., 2020). This statement is supported by Riyandi et al. (2020) which states that the use of technology as a learning medium during the *COVID-19* is an alternative solution to be able to continue to carry out learning activities remotely(Gaffar & Biology, 2020). According to research conducted by Hamidy (2021) shows that *google classroom* is effective for the learning process and influences student learning outcomes. *Google classroom* can be a means of discussion, distribution of material, collection of assignments and even assessing the submitted assignments. According to(Suhada et al., 2020) the use Online learning becomes good and effective with google classroom.

In accordance with research conducted by (Subekti et al., 2020) which states that *video conferencing* is very practical to use for online learning. By conducting face-to-face, *online* teachers will find it easier to know the learning conditions of their students (Subekti et al., 2020) and in the delivery of material can also be explained directly on the spot. These two media are used, namely *synchronous* and *asynchronous* applied learning, the *synchronous* can be through *video conferencing media.* learning *asynchronous* media *google classroom*. Thus, it will be able to maximize the implementation of learning with the PjBL model. This is in line with research conducted by Hamidy (2021) which states that *google classroom* and *video conferencing* can improve the quality of mathematics learning.

The novelty in this research is the use of the PjBL model assisted by *google classroom* and *video conferencing* to accommodate the digitization of learning during the pandemic to improve students' mathematics learning outcomes. With the application of the PjBL model which is considered appropriate to the needs of students in online learning, it is also accompanied by learning media that will make it easier for both students and teachers in learning.

Problem of Research

Based on the description above, the formulation of the problem in this study is as follows:
Is the learning outcomes in mathematics taught using the *project based learning* (PjBL) model assisted by *google classroom* and *video conferencing* better than the mathematics learning outcomes of students who are taught using conventional learning models.

Method

Research Model

This research belongs to the category of quasi-experimental. Quasi-experiments were used to observe the effect that emerged from the treatment given to each group in which variable control was only carried out on one variable that was observed to be very dominant (Sugiono, 2013). This study linked two groups, namely the experimental and control groups. For the experimental group to be taught using the PjBL while the control group was taught using conventional learning.

Participants

The study population was class XI in SMA Negeri 1 Selemadeg, Bali, Indonesia, total population is 148 students. The sample selection by *cluster random sampling technique.* XI MIPA 1 is the experimental class with as many as 29 people while the control group is class XI MIPA 2 with as many as 29 people. This research was conducted from February to March and it was conducted by giving different treatment between the experimental class and the control class. The experimental class was given treatment with a *project based learning* (PjBL) model assisted by *google classroom* and *video conference* , while the control class was given conventional learning treatment. After being given treatment then given *post-test*.

Math Achievement Test

The instrument in this study was a post-test in the form of a description test consisting of 5 *essays* that were used to measure student learning outcomes, especially in the cognitive domain. referring to the taxonomy of blooms then student learning outcomes can be divided into three, namely cognitive, affective and psychomotor. in this study focused on the cognitive dimensions of the new bloom taxonomy consist of six categories, namely C1, C2, C3, C4, C5, and C6. Implementation *post-test* was given at the end, namely after the two sample classes were given treatment. The post-test questions *contain* function derivative material. The post-test had been tested before the *post-test* was given to students. The instrument tests carried out are content validity tests, item validity tests using Carl Pearson's product moment correlation and reliability tests using *Alpha Cronbach's*. For the results of the calculation can be seen in appendix 1.

Data Analysis

Data on students' mathematics learning outcomes were obtained *post-test* which was given to the experimental class and the sample class after being given treatment. The *post-test* consists of 5 description questions. The research data were analyzed using a t-test (*independent sample t-test)* assisted by the SPSS 22.0 program. Prior to the t-test, the requirements analysis test was carried out, including the normality test using the *Lilifors* and the homogeneity of variance test using the Levene technique

Procedure

This researcher used the research design of the Posttest Only Control Group Design experiment. Experimental classes were given treatment with the Project based learning model assisted by Google Classroom and video conferencing while control classes were given treatment with conventional learning. Learning begins on February 21 and ends on March 31, 2022. In this study, the project based learning model assisted by Google Classroom and video conferencing will run projects based on the theme given by the teacher. While the control class with conventionally conducts its usual learning. The learning process is carried out online. In the experimental class, it uses google classroom media and video conferencing in the learning process.

Figure 1. Learning process with video conferencing

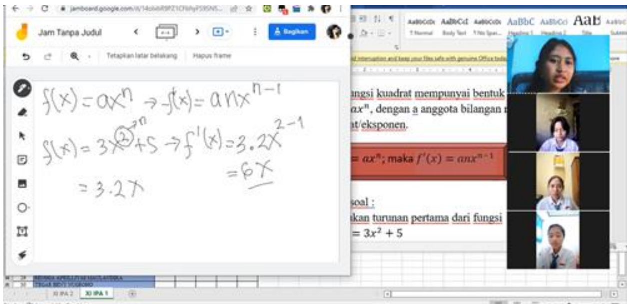


Figure 2. Learning process with video conferencing

Figure 3. Learning process with google classroom

Results

To determine the effect of the PjBL model model assisted by *google classroom* and *video conferencing* on students' mathematics learning outcomes used testing with *independent sample t-test.*with SPSS 22.0 tools. The data used as research data were measured by the implementation of the *post-test* at the end of the treatment for the two sample classes scores *post-test*. The score is used as a reference to determine student learning outcomes, especially in the cognitive domain. The *post-test* are presented as follows:

Value Data *Post-test* Experimental Class

After being given treatment, the experimental class will carry out the *post-test* to obtain data in the form of scores that will be analyzed as data on students' mathematics learning outcomes. The number of students in the experimental class is 29 students. The following are descriptive statistics of the *post-test* presented in Table 1:

Table 1.

Post-test Experimental Class

N	Min	Max	Mean	Std. Deviation
29	50	95	74.31	10.58

Based on table 1 above, it can be seen that the average mathematics learning outcomes reached 74.31. Of the 29 students, there were 17 students with grades above the average, and the rest below the average 12 students. The minimum score obtained in the experimental class is 50 and the maximum value is 95. The standard deviation of the data is 10.58. For more details, the following is a group diagram of experimental class students based on the category of mathematics learning outcomes.

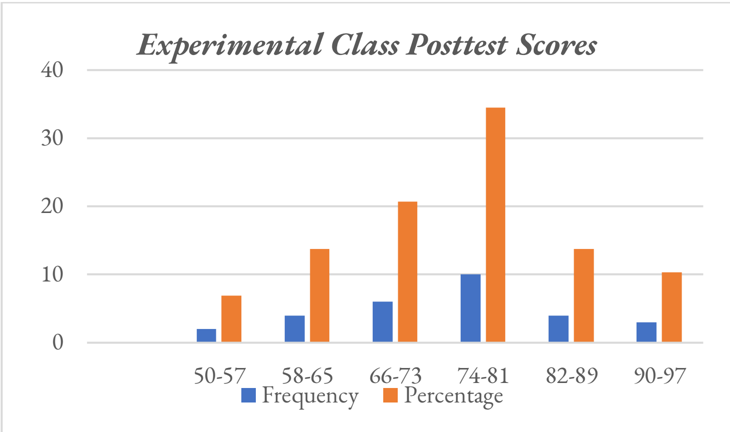


Figure 4. Scores distribution chart of control class

From the picture above, it is known that the percentage of students who score in the range of 50-57 is 7%, 58-65 is 14%, 66-73 is 21%, 74-81 is 34%, 82-89 is 14%, 90-97 is 10%.

Scores of *Post-test* Control Class

After being given treatment, the control class will carry out the *post-test* to get data in the form of scores that will be analyzed as data on students' mathematics learning outcomes. The number of students in the control class is 29 students. The following are descriptive statistics of the *post-test* presented :

Table 2. Post-test Control Class

N	**Min**	**Max**	**Mean**	**Std. Deviation**
29	35	90	63.1	13.850

Based on table 2 above, can be mentioned mathematics learning outcome reaches 63.1. Of the 29 students, there were 14 students who had grades above the average, and the rest were below the average of 15. The minimum score obtained in the control class is 35 and max is 90. With a std. Deviation of 13.85. For more details, the following is a group diagram of control class

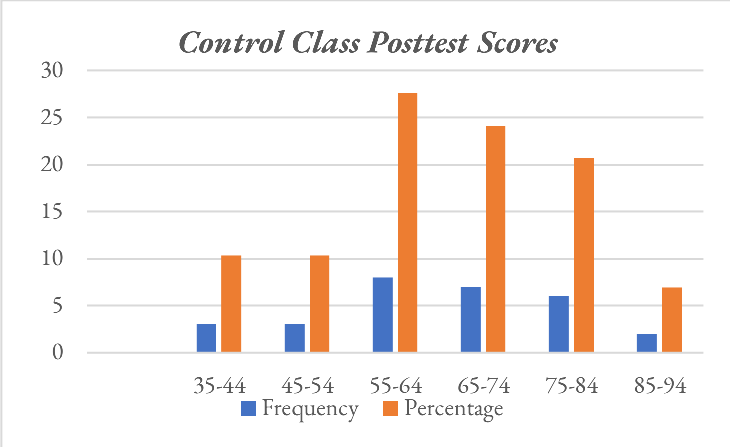


Figure 5. Scores distribution chart of control class

From the picture above, it is known that the percentage of students who score in the range of 35-44 is 10%, 45-54 is 10%, 55-64 is 28%, 65-74 is 24%, 75-84 is 21%, 85-94 is 7%.

Hypothesis Test

Testing is done to prove whether the proposed hypothesis is proven or not. Before entering the hypothesis test, a prerequisite test must be carried out first. The prerequisite tests include normality test and homogeneity test.

Normality Test of Research Data Normality

Test distribution data is used to find out.whether.data in a sample group used the origin of the normal population. The data can be declared normally distributed if the result of the probability significance value is > α :

Table 3. Normality value

Test of Normality			
	Kolmogorov-Smirnov		
	Statistic	Df	Sig
Experimental Class	0.135	29	0.189
Control Class	0.105	29	0.2

After the test of the normality test of the data on the value of students' mathematics learning outcomes above, it was obtained that the experimental class had a significant value and the control class obtained a significance value. From these data, it can be concluded that the significance of the probability of the experimental class and the control class was greater than 0.05. This means that the data on the mathematics learning outcomes of the experimental class and control class students is normally distributed.

Homogeneity Test of Research Data

After the data is declared to be normally distributed, the prerequisite test is continued with the homogeneity test. The homogeneity test is used to show whether the two-sample data come from populations that have the same variance (Sari et al., 2017). The data can be declared homogeneous if the results of the probability significance value >α. The homogeneity test results obtained are presented in Table 4 below:

Table 4. Homogeneity test

Test of Homogeneity of Variances			
Learning Outcomes:			
Levene Statistic	df1	df2	Sig
2.865	1	58	0.96

Based on the results of the analysis of the homogeneity test of the students' mathematics learning outcomes above, the significance probability value was obtained. From these data, it can be concluded that the experimental class and control class students' mathematics learning outcomes data had a homogeneous distribution of variance.

After passing the prerequisite test and the data is declared normally distributed and has a homogeneous variance, the test can be continued. Hypothesis testing in this study was conducted by using *Independent sample t test* with SPSS *version 22.0 for windows*.

Table 5. Hypotesis test

	df	Mean Difference	t	Sig.
Equal variances assumed	56	11.2	3.462	0.01
Equal variances not assumed	52.38	11.2		

Based on the table above, it shows that the probability significance value is 0.01 with the value because of the probability significance. This means that the mathematics learning outcomes of class XI high school students are taught using the PjBL model assisted by *google classroom* and *video conferencing* is better than the students' mathematics learning outcomes who are taught using conventional learning

Discussion and Conclusion

Student learning outcomes are very important in a student education cycle (Juniantari, 2017). Learning outcomes show a success in learning (Datu et al., 2022). Learning outcomes can be measured, one of which is by paying attention to the value of the test or the value in working on the task. Learning outcomes that can be measured through a score for doing assignments or tests are called learning outcomes in the cognitive domain. In order to obtain learning outcomes in the good category the teacher must be able to present a lesson that can stimulate students to understand the material being studied (Aida et al., 2017). Therefore, an increase in learning outcomes is very important because currently student learning outcomes, especially in mathematics, are at a low level every year (Puspendik, 2019).

Project-based learning that supports students' ability to express what they learn, asking questions and expressing their ideas allows them to form their own knowledge and relate their knowledge to everyday problems (Hutapea & Mariati, 2021). In a pandemic situation like the current one, learning is done online. In addition to selecting the right model, it is necessary to have a media that can support the learning process (Agar et al., 2022). *Google classroom* and *video conferencing* are effective media to collaborate with to support the implementation of the syntax of the PjBL model during this pandemic. This study examines the effect of a project-based model (PjBL) assisted by *google classroom* and *video conferencing* on students' mathematics learning outcomes. Two sample classes were applied, namely the experimental class and the control class.

In the experimental class, the PjBL model was applied with the help of Google Classroom *and* video *conferencing*. This means that students in the experimental class are taught the PjBL syntax and are assisted by google classroom learning media *and* video *conferencing* as a support support. In the experimental class, the learning process is dominated by making projects carried out by students in groups. The learning steps are: (1) Determining the fundamental questions: (2) Designing a project plan: (3) Designing a schedule; (4) Guiding students and seeing the progress experienced by students; (5) Checking the results obtained (6) Evaluating or providing criticism and suggestions (Prakarsa, 2013). In the process of working on this project, students will be able to form their own knowledge and be able to link the material they get with problems in everyday life (Salman et al., 2017). In the process of working on a project that has been structured, students will also get assignments and can be responsible for their work and groups. This will result in students being more active in learning (Hasri, 2021). The control class is taught with conventional learning. Conventional learning in this study means the model given by the teacher at the school. In the learning process, the control class is dominated by giving homework (PR).

After being given different treatments in the two sample classes, the *post-test*. *Post-test* was given to obtain data in the form of scores, which were used as research data. After the data was obtained, the data was tested by using the *independent sample t-test.* Based on the results of the tests that have been carried out, it is known that the mathematics learning outcomes of students taught by the PjBL model assisted by *google classroom* and *video conference* are better than conventional learning. It is also found that the average value of the experimental class is higher than the control class. This can happen because of the benefits obtained from the application of the PjBL model google *classroom* and *video conferencing*. This causes students' knowledge to be built properly and each student can explore more knowledge and solve problems related to everyday life better (Kusilawati et al., 2019).

In working on projects students are guided to turn their experiences into problem solving. The problems given are various, including problems made by students themselves and there are also problems given directly by the teacher. Students are given the freedom to explore various sources of literacy to solve problems that are already available. In making projects students are directed to make a summary of material taken from several literacy sources and is accompanied by problem solving. The entire project will be in the form of a paper. During project work activities, students are facilitated to ask questions they have through *video conference* or *google classroom.* As the final stage, students will collect the results of their projects and present them to friends and teachers through *video conference media.*

In line with research by (Hutapea & Mariati, 2021) which states that the PjBL model has a good effect on student learning outcomes, especially at the high school level. Using the project work, students will be able to form their own knowledge due to the literacy search stage and use this knowledge to solve problems. Goals set in project work, ensure learning efficiency with project work, and strengthen the basic knowledge that students already have before even that knowledge will increase after project work (Akyol et al., 2022). In addition to forming knowledge of project-based learning, it has a high impact on increasing student learning outcomes (Kusilawati et al., 2019). This statement is in line with research conducted by Eliza et al. (2019) which states that in the PjBL model students will be able to play an active role in learning and students can explore freely all the knowledge they want to use to complete projects. However, in several studies that have been carried out related to the application of the PjBL model, the use of learning media is less and some even do not use learning media at all.

Learning media is one of the important components in the success of the learning process (Riyandi et al., 2020). The high learning outcomes in the experimental class are also supported by appropriate learning media, namely *google classroom* and *video conferencing* actively and periodically to facilitate online meetings. This will cause students to be more enthusiastic about learning (Salsabila et al., 2020). This is in line with research conducted by which proves that many students are very happy with the application of *Google Classroom* when studying mathematics during a pandemic. Even students find it easy to apply to the *google classroom* at the stage of learning Mathematics(Gaffar & Biologi, 2020). In addition, the suitability of the results is also shown in a study conducted by Herni Ari Subekti, et al (2020) that state use *of video coverage* as an interactive learning media shows its practicality and effectiveness. With the use of *video coverage* students and teachers can be more flexible in delivering material and meet face to face even though they are limited by distance (Riyandi et al., 2020). This will have a good effect on the learning process. Because teachers will find it easier to supervise students in the learning process (Fitra Prisuna, 2021).

The implication of this research is to improve students' mathematics learning outcomes through the application of the PjBL model assisted by *google classroom* and *video conferencing.* Seeing the benefits of implementing the PjBl model with the help of *google classroom* and *video conference* shows that the contribution of this research is to determine a contribution to the appropriate learning model applied in the 4.0 revolution era and able to improve students' mathematics learning outcomes so that it can be used as a reference for teachers in the learning process at class. Based on data analysis and discussion of research results, it can be concluded that students' mathematics learning outcomes taught using the PjBL model *assisted by google classroom* and *video conferencing*, it is better than the students' mathematics learning outcomes who are taught using conventional learning

Recommendations

Based on the results of research that has been done and see that the PjBL model assisted by *google classroom* and *video conferencing* has a good influence on student learning outcomes, the PjBL model assisted by *Google Classroom* and *video conferencing* can be recommended, especially in the purpose of improving student learning outcomes. Because seeing the effect given to improving student learning outcomes. In addition, seeing the success of the implementation of the PjBL model, there are also limitations, namely the learning process using the PjBL model assisted by *Google Classroom* and *video conference*. Researchers feel that learning will be maximized with several solutions. One of them is for further research it is recommended to apply this PjBL model using the help of video tutorials to make it easier for students to know the stages of project work to be carried out, and when project collection is recommended to be accompanied by making video presentations to streamline presentation time and presentation of results. projects can be maximized.

Limitations of Study

In this study there are also limitations, namely in the collection and presentation of project results by students. In this study, students only collected and had little time to present their project results. So, within these limitations, a solution can be used, namely adding a video presentation at the end of the lesson to accommodate students so that they can present their projects optimally and can be watched by other students.

Acknowledgments

Researchers would like to thank schools, teachers and students who have been willing to participate and be part of this research.

Biodata of the Authors

I Putu Pasek Suryawan, S.Pd., M.Pd. is Senior Lecturer in Mathematics Education Study Program, Faculty of Mathematics And Natural Sciences, Universitas Pendidikan Ganesha, Indonesia. Her interesting research include student learning in mathematics, especially in improving elementary and high school mathematics learning based on problems, culture, and character. E-mail : putu.pasek@undiksha.ac.id Phone : 085737233710
Googlescholar : https://scholar.google.com/citations?user=230JN-AAAAAJ&hl=id&oi=ao
Scopus: https://www.scopus.com/authid/detail.uri?authorId=57202611510

Ni Putu Ayu Gandhita Liana is student in Mathematics Education Study Program, Faculty Of Mathematics And Natural Sciences, Universitas Pendidikan Ganesha, Indonesia. She born in Tabanan, December 8th 1999. She interesting research include student learning in mathematics. E-mail : ayu.gandhita@undiksha.ac.id Phone : 081246357015
Mendeley : gandhitaliana12@gmail.com

Dr. I Made Sugiarta, M.Si is Senior Lecturer in Mathematics Education Study Program, Faculty Of Mathematics And Natural Sciences, Universitas Pendidikan Ganesha, Indonesia. Her interesting research include how is the study of the evaluation of mathematics learning
E-mail : made.sugiarta@undiksha.ac.id
Phone : 085965997443

I Gusti Nyoman Yudi Hartawan, S.Si., M.Sc. is Senior Lecturer in Mathematics Education Study Program, Faculty Of Mathematics And Natural Sciences, Universitas Pendidikan Ganesha, Indonesia. Her interesting research include student learning in mathematics, research and development of media learning, and mathematical powerE-mail : yudi.hartawan@undiksha.ac.id Phone : 081933033239
Googlescholar :
https://scholar.google.com/citations?user=ODTEonQAAAAJ&hl=en&oi=sra

References

Agar, G., Kegiatan, T., & Aktif, S. (2022). *Analisis Kebutuhan Media Pembelajaran Digital Bagi*. *2*(02), 264–274.

Aida, N., Kusaeri, K., & Hamdani, S. (2017). Karakteristik Instrumen Penilaian Hasil Belajar Matematika Ranah Kognitif yang Dikembangkan Mengacu pada Model PISA. *Suska Journal of Mathematics Education*, *3*(2), 130. https://doi.org/10.24014/sjme.v3i2.3897

Akmal, M. J., & Santaria, R. (2020). Mutu Pendidikan Era Revolusi 4.0 di Tengah Covid-19. *Journal of Teaching Dan Learning Research*, *2*(2), 1–12. http://ejournal.iainpalopo.ac.id/index.php/JTLR/article/view/1415

Akyol, T., Şenol, F. B., Yaşar, M. C., Yaşar, C., & The, M. (2022). *The Effect of Project Approach-Based Education on Ch ildren ' s Early Literacy Skills To cite this article : The Effect of Project Approach-Based Education on Ch ildren ' s Early Literacy Skills*.

Andita Putri Surya, Stefanus C Relmasira, A. T. A. H. (2018). *penerapan model pembelajaran project based learning (pjbl) untuk meningkatkan hasil belajar dan kreatifitas siswa kelas iii sd negeri sidorejo lor 01 salatiga*. *6*(1), 41–54.

Asmuni, A. (2020). Problems of Online Learning in the Covid-19 Pandemic Period and Solutions to Solve it. *Journal of Pedagogy*, *7*(4), 281–288.

Datu, A. R., Tumurang, H. J., & Sumilat, J. M. (2022). Pengaruh Motivasi Belajar Terhadap Hasil Belajar Siswa di Tengah Pandemi Covid-19. *Jurnal Basicedu*, *6*(2), 1959–1965. https://doi.org/10.31004/basicedu.v6i2.2285

Eliza, F., Suriyadi, S., & Yanto, D. T. P. (2019). Peningkatan Kompetensi Psikomotor Siswa Melalui Model Pembelajaran Project Based Learning (PjBL) di SMKN 5 Padang. *INVOTEK: Jurnal Inovasi Vokasional Dan Teknologi*, *19*(2), 57–66. https://doi.org/10.24036/invotek.v19i2.427

Fatma, H. (2021). Kreativitas Peserta Didik Dalam Pembelajaran Bioteknologi Dengan Pjbl Berbasis Steam. *Pedagonal : Jurnal Ilmiah Pendidikan*, *5*(1), 7–14. https://doi.org/10.33751/pedagonal.v5i1.2574

Fitra Prisuna, B. (2021). Pengaruh Penggunaan Aplikasi Google Meet terhadap Hasil Belajar. *Jurnal Penelitian Ilmu Pendidikan*, *14*(2), 45–49. http://journal.uny.ac.id/index.php/jpiphttps://doi.org/10.21831/jpipfip.v14i1.39160

Gaffar, A. A., & Biologi, P. (2020). *Optimalisasi penggunaan google classroom sebagai alternatif digitalisasi dalam pembelajaran jarak jauh (pjj)*. *5*, 23–36.

Hamidy, A. (2021). Zoom Meeting vs Google Classroom : Perbedaan Hasil Belajar Matematika Berdasarkan Platform Pembelajaran Daring. *Tarbiyah Wa Ta'lim: Jurnal Penelitian Pendidikan Dan Pembelajaran*, *8*(1), 61–68.

Hasri. (2021). Meningkatkan Prestasi Belajar Siswa Melalui Pendekatan Project Based Learning pada Mata Pelajaran Matematika. *Didaktika: Jurnal Kependidikan*, *10*(1), 45–52.

Hutapea, J., & Mariati, P. S. (2021). *Pengaruh model pembelajaran project based learning (PjBL) terhadap hasil belajar siswa SMA*. 54–60.

Izza, A. Z., Falah, M., & Susilawati, S. (2020). Studi Literatur: Problematika Evaluasi Pembelajaran Dalam Mencapai Tujuan Pendidikan Di Era Merdeka Belajar. *Konferensi Ilmiah Pendidikan Universitas Pekalongan 2020*, 10–15. https://proceeding.unikal.ac.id/index.php/kip

Juniantari, I. G. A. S. (2017). Pentingnya Peningkatan Kompetensi Guru Dalam Pencapaian Hasil Belajar Siswa. *Jurnal Ilmu Pendidikan*, *1*(3), 1–12.

Kusilawati, J., Wiryokusumo, I., & Adi Walujo, D. (2019). the Implementation of Project Based Learning, Demonstration and Learning Style To Improve Learning Outcomes in Vocational High School. *International Journal of Education and Research*, *7*(1), 55–62. www.ijern.com

Mustafa, S., Mustikaningsih, H., & Imayanti, R. (2021). Pembelajaran Tatap Muka (PTM) pada Masa Pandemi Covid-19 di SMA. *Kementerian Pendidikan, Kebudayaan, Riset, Dan Teknologi*, 1–35.

Nasution, M. K. (2017). *Penggunaan Metode Pembelajaran Dalam Peningkatan Hasil Belajar Siswa*. *11*(1), 9–16.

Oktaviana, D., & Prihatin, I. (2018). Analisis Hasil Belajar Siswa Pada Materi Perbandingan Berdasarkan Ranah Kognitif Revisi Taksonomi Bloom. *Buana Matematika : Jurnal Ilmiah Matematika Dan Pendidikan Matematika*, *8*(2:), 81–88. https://doi.org/10.36456/buana_matematika.8.2:.1732.81-88

Prakarsa, A. (2013). *PROJECT BASED LEARNING (PjBL)*.

Reflianto, & Syamsuar. (2018). Pendidikan dan Tantangan Pembelajaran Berbasis Teknologi Informasi di Era Revolusi Industri

4.0. *Jurnal Ilmiah Teknologi Pendidikan*, *6*(2), 1–13.

Riyandi, A., Aulianita, R., Wiyatno, A., Triantori, V., & Musyaffa, N. (2020). Pemanfaatan Teknologi untuk Pembelajaran Jarak Jauh di Masa Pandemi Covid-19. *Jurnal AbdiMas Nusa Mandiri*, *2*(2), 37–42. https://doi.org/10.33480/abdimas.v2i2.1682

Salman, L., Suleman, N., & Kilo, A. La. (2017). Pengaruh Model Pembelajaran Project Based Learning (PjBL) yang Disertai dengan Peta Konsep terhadap Hasil Belajar Siswa Kelas XI TPHP SMK Negeri 2 …. *Jambura Journal of Educational*, *12*, 193–200. https://www.neliti.com/publications/277432/pengaruh-model-pembelajaran-project-based-learning-pjbl-yang-disertai-dengan-pet

Salsabila, U. H., Lestari, W. M., Habibah, R., & Dahlan, U. A. (2020). *Pemanfaatan Teknologi Media Pembelajaran di Masa Pandemi*. *2*(2).

Sari, A. Q., Sukestiyarno, Y. L., & Agoestanto, A. (2017). *Prasyarat Uji Normalitas dan Homogenitas*. *6*(2), 168–177.

Subekti, H. A., Nubaiti, N., Masilawati, M., & Fitria, H. (2020). Pemanfaatan Video Conference Sebagai Media Pembelajaran Interaktif pada Mata Pelajaran Produktif di Sekolah Menengah Kejuruan. *Prosiding Seminar Nasional Program Pascasarjana Universitas PGRI Palembang*, 427–437. https://jurnal.univpgri-palembang.ac.id/index.php/Prosidingpps/article/view/3855

Sugiono, D. (n.d.). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Alfabeta CV.

Suhada, I., Kurniati, T., Pramadi, A., & Listiawati, M. (2020). Pembelajaran Daring Berbasis Google Classroom Mahasiswa Pendidikan Biologi pada Masa Wabah Covid-19. *Jurnal Pembelajaran Daring*, *2019*, 1–9. http://digilib.uinsgd.ac.id/30584/

Wijaya, I. M. ., Suweken, G., & Mertasari, N. M. (2016). Pengaruh Penerapan Model Pembelajaran Blended Learning Terhadap Motivasi Berprestasi Dan Prestasi Belajar Matematika Siswa Sma Negeri 1 Singaraja. *Jurnal Wahana Matematika Dan Sains*, *10*(2), 36–47.

Yutantin. (2018). *Wall Magazine Project in Teaching Narrative Writing*. *October*, 130–144.

Appendix 1. Math Achievement Test

Item validity tests

In this analysis, the data used is data on the results of the instrument trial test consisting of 5 questions. Validity analysis using product moment correlation with SPSS tool version 22.0 for windows.

Test criteria

1. Calculation results r_{xy} consulted in the table product moment with n=30 or df=n-2 If $r_{xy} > r_{tabel}$ then the question item is valid.
2. The level of significance used is α=5%

Correlations							
		Q 1	Q 2	Q 3	Q 4	Q 5	Total score
Question 1	Pearson Correlation	1	0.281	0.143	0.027	0.108	0.343
	Sig. (1-tailed)		0.066	0.225	0.444	0.284	0.032
	N	30	30	30	30	30	30
Question 2	Pearson Correlation	0.281	1	0.109	0.277	0.336	0.364
	Sig. (1-tailed)	0.066		0.282	0.069	0.035	0.024
	N	30	30	30	30	30	30
Question 3	Pearson Correlation	0.143	0.109	1	0.02	0.421	0.769
	Sig. (1-tailed)	0.225	0.282		0.548	0.01	0
	N	30	30	30	30	30	30
Question 4	Pearson Correlation	0.027	0.277	0.02	1	0.013	0.351
	Sig. (1-tailed)	0.44	0.069	0.458		0.473	0.029
	N	30	30	30	30	30	30
Question 5	Pearson Correlation	0.109	0.336	0.421	0.013	1	0.727
	Sig. (1-tailed)	0.284	0.035	0.01	0.473		0
	N	30	30	30	30	30	30
Total score	Pearson Correlation	0.343	0.364	0.769	0.351	0.727	1
	Sig. (1-tailed)	0.032	0.024	0	0.029	0	
	N	30	30	30	30	30	30

From the table above, it is obtained that r_{xy} question 1 = 0.343, r_{xy} question 2 = 0.364, r_{xy} question 3 = 0.769, r_{xy} question 4 = 0.351 and r_{xy} question 5 = 0.727. From the table r product moment obtained r_{table} =0.306. It is thus obtained that the r_{xy} for all the questions > r_{table}. Based on the test criteria, it can be concluded that all the question items on the instrument are included in the valid criteria.

Reliability tests

In this analysis, the data used is data on the results of the instrument trial test consisting of 5 questions. Reliability analysis using Alpha Cronbach's with SPSS.

Test criteria

1. Calculation results r_{11} consulted in the table product moment with n=30 or df=n-2 If $r_{11} > r_{tabel}$ then the question item is reliabel.
2. The level of significance used is α=5%

Case Processing Summary			
		N	percentace
Cases	Valid	30	100

Excluded	0	0
Total	30	100

Reabillity Statistic	
Cronbach's Alpha	N of Items
0.358	5

From the table above, it is obtained that r_{11}=0.358. from the table r obtained r_{table}=0.306. Thus obtained $r_{11} > r_{table}$. Based on the test criteria, it can be concluded that all question items on the instrument are included in the reliable criteria

JMETP
Journal for the Mathematics Education and Teaching Practices, 3(2), 71-85, Dec 2022
e-ISSN: 2717-8587
dergipark.org.tr/jmetp

Young Wise Publishing
youngwisepub.com
gencbilgeyayincilik.com © 2022

Research Article

Effectiveness of loci method to increase mathematics learning achievement of grade 5th elementary school students

Afifah Dian Permata[1]* and Nur Eva[2]

Faculty of Psychology, Malang State University, Indonesia

Article Info

Received: 6 September 2022
Accepted: 19 December 2022
Available online: 30 Dec 2022

Keywords:
Elementary school students
Loci Method
Mathematics achievement

Abstract

Mathematics learning achievement of elementary school students is determined by the learning method used by the teacher. The learning method needed is a method that can help maximize student memory so that students can remember the material well. The Loci method connects certain objects with specific locations so that the individual may easily recall them. The purpose of this study was to empirically test the effectiveness of the loci method on mathematics learning achievement for elementary school students. This experimental research used a quasi-experimental design, with a one-group research design. Six elementary school students participated in this study. Pretest-posttest design with mathematics achievement test and the loci method treatment module were utilized as instruments. Data were analyzed by the paired sample t-test. The results of data analysis found that there is a difference between pre-test and post-test and that the loci approach helps enhance mathematics achievement. The Cohen's d Effect Size test resulted in a score of 77.4%, indicating that the Loci Method is highly effective in boosting mathematics learning achievement for students in elementary school. The implication of this research is that schools are expected to train mathematics teachers to use the loci method to improve students' mathematics learning achievement.

To cite this article

Permata, A.D. & Eva, N. (2022). Effectiveness of loci method to increase mathematics learning achievement of grade 5th elementary school students. *Journal for the Mathematics Education and Teaching Practices, 3*(2), 71-85.

Introduction

Understanding mathematics is strongly related to numeracy skills. This determines the direction and technique of studying mathematics to make it more contextually (Rowan-Kenyon et al., 2012). The Indonesian Ministry of Education has created a national assessment for students in Indonesia on literacy and numeracy components (Zubaidah, 2021). This National Assessment is an evaluation program to improve the quality of education which consists of a minimum competency assessment in literacy and numeracy, a character survey and a survey of the learning environment. The National Assessment is carried out with the aim of improving students' critical thinking and reasoning skills in literacy and numeracy aspects which are expected to later increase the Program for International Student Assessment (PISA) scores and Trends in International Mathematical and Science Study (TIMSS) scores (Sriyatun, 2020). Students of Indonesia were placed 44th out of 49 countries based on the latest data from TIMSS, which was followed by Indonesia in 2015, for the assessment of learning achievement in mathematics and science for students from various areas of the

[1] Student, Faculty of Psychology Education, Malang State University, Indonesia. E-mail: afifahdianpermata117@gmail.com. ORCID: 0000-0002-8741-4892
[1] Assoc. Prof. Dr., Chief of Psychology Department, Faculty of Psychology Education, Malang State University, Indonesia. E-mail: nur.eva.fppsi@um.ac.id Phone: ORCID: 0000-0003-3584-5049

world. According to the most recent PISA 2018 data, which tests students' science, reading, and math skills around the world, Indonesia's maths score ranks 73rd out of 78 countries (Dian, 2022).

The results of the National Assessment carried out in 2021, when evaluated through the lens of minimum competency assessment, demonstrate that 1 in 2 students throughout Indonesia have not attained the requisite literacy competence, and 2 out of 3 students throughout Indonesia have not reached the minimum numeracy competence (Rosa, 2022). According to Swasty (2022), among the several levels: elementary school, junior high school, and senior high school, the elementary school has the highest percentage of education units that require special intervention, particularly in the field of numeracy. This can be concluded that the mathematical ability of elementary school students in Indonesia is relatively low, which can be seen in their numeracy abilities.

Mathematical achievement, specially for numeracy abilities must be developed. According to Retnoningsih (2015) and Binkley et al. (2012), strengthening mathematical abilities can boost the ability to think rationally, analytically, systematically, critically, and creatively, allowing individuals to access, manage, and use knowledge to deal with dynamic situations. The numeracy skills are important to improve because if they are not improved, it will have a negative impact on society's survival, including the difficulty of continuing education, low competitiveness, and being easily duped by hoaxes circulating in the community (Rosa, 2022).

The capacity to perceive mathematical information as well as employ arithmetic operations and numbers that surround persons in everyday life is referred to as numeration (Sternberg, 2012). The capacity to conceptualize utilizing mathematical principles to solve daily situations is referred to as numeration (Papadopoulos, 2013). In reality, numeracy entails being able to apply the notion of counting to a variety of circumstances in the world (Cohen, 2016).

The concept of numeracy is similar to the loci method, which relates knowledge about specific items with specific locations in the expectation that the subject would recall the information more easily (Solso et al, 2008). According to Riccomini (2015), concerning mathematics achievement, the mnemonic method (which consists of the loci method, dependent word system method, keyword method, acronym method, and acrostic method) is a way that can help maximize student memory so that students can remember the formulas used in mathematics and use them appropriately. According to Willingham (2021), memory is required for recycling knowledge since it is utilized to obtain new knowledge or answer problems.

Students will be able to improve their learning results by being given a method that addresses the issue of low achievement in mathematics. Additionally, this method may have a positive effect on teachers as well as students, making it easier for them to carry out their educational duties and helping students develop critical thinking and social skills (McLean & Connor, 2015).

The loci method is successfully applied, and Qureshi's (2014) research demonstrates that interactive learning utilizing the loci method can improve student performance as evidenced by an increase in the percentage of correct answers provided by students when compared to independent study sessions that use assessments through regular worksheets. Additionally, studies by Syanthi et al. (2016) demonstrate that applying the Loci Method on 54 students of scientific courses can help you retain information more effectively than just reading it aloud. Similarly, Retnoningsih (2015) demonstrated in her study that the Loci Method had an impact on how students yunior high school associated items with geometric formulae. Peek (2016) conducted previous research on the Loci Method, which is used in learning French verbs for high school students, and it is known that the loci method is effective in learning French verbs. Based on the explanation above, the authors are interested in conducting experimental research on how the effectiveness of the loci method to improve mathematics learning achievement of elementary school students

Mathematics Learning Achievement

Learning achievement is referred to as the provision of value as a result of student learning after the examination (Khalalia, 2015). Learning achievement, according to Zimmerman (2013), is a learning result that cannot be isolated from learning activities, where learning activities are a process and learning achievement is a learning process. the outcomes of the learning procedure So, based on the words of the two scholars above, it is possible to conclude that learning achievement is the outcome obtained by students after engaging in learning activities.

Mathematics achievement is the outcome obtained by students after participating in mathematics lessons, which results in changes in students' self in the form of new mastery and skills as evidenced by grades (Andersson & Palm, 2017). According to Huang et al. (2012), mathematics achievement is the outcome obtained by students after completing the entire series in the mathematics learning process. Thus, based on these two perspectives, it is possible to conclude that mathematics achievement is the outcome gained by students after engaging in mathematical learning activities, resulting in certain changes in students in the form of grades.

According to several researchers, several factors influence student achievement. According to Kauffman (2015), the factors that affect student learning achievement include 1) internal factors that come from within students, 2) external factors that come from the environment, and 3) student learning approaches, which include strategies and methods of learning that students use. Han et al. (2015) also discusses the following aspects that influence learning achievement: internal factors and external factors.

- internal factors consisting of:
    - physiological factors, namely the health of the body and the five senses
    - psychological factors, namely intelligence, attitude, motivation,
- external factors consisting of:
    - family environmental factors, namely family socioeconomic, parental education, parental attention, and the atmosphere of family relationships,
    - school environmental factors, namely infrastructure, teacher and student competencies, curriculum and teaching methods
    - community environmental factors, namely socio-cultural, and participation in education.

The 2013 curriculum aims to make changes in character education that are integrated by emphasizing the cognitive, affective, and psychomotor aspects to improve student learning achievement that is more directed at practice than just material, and is also capable of bringing out student creativity through the skills (Salim & Mujtahidah, 2020). The three aspects of student achievement correspond to the three aspects of learner achievement identified by Mirzeoglu (2016), which are cognitive, affective, and psychomotor. According to Stoet and Geary (2018), each aspect of mathematics learning achievement is explained as follows:

- Cognitive aspects are learning achievements related to the ability to think, which includes the ability to comprehend, memorize, apply, analyze, synthesize, and evaluate.
- The affective aspect is a learning achievement whose achievement is related to feelings and emotions consisting of interests, attitudes, self-concepts, and values in attitude to overcome problems that are around.
- The psychomotor aspect is a learning achievement whose achievement is related to the muscle skills and physical strength of the individual.

The objective of assessing in this study is limited to learning achievement in mathematics, with the aspects used being cognitive. The material used to assess students' mathematical learning achievement is following the mathematics teacher's manual, with fractions material and velocity and discharge material.

Table 1. Fractions, Velocity, and Discharge Indicators

Material	Indicator
1. Fraction	1.1 Identifying the forms of fractions and calculating the addition and subtraction of fractions with different denominators.
	1.2 Solving problems involving addition and subtraction of two fractions with different denominators

	1.3 Multiplication and division of fractions with different denominators
	1.4 Solving problems related to multiplication and division of fractions
2. Speed and Discharge	2.1 Identifying the comparison of two different quantities (velocity as a comparison of distance with time, discharge as a comparison of volume and time)
	2.2 Solving problems related to the comparison of two different quantities (velocity, discharge)

Loci Method

The mnemonic approach includes the loci method. The mnemonic approach is a method of memorizing (Pressley et al., 2016). The mnemonic approach, as defined by McCabe (2015), is a technique that employs familiar associations to improve the storage and retrieval of information in memory. According to Solso et al (2008), the loci approach is defined as follows: 1) employing easy-to-understand correlations or relationships, 2) storing or coding information to the brain, and 3) memorizing stored knowledge by retrieving the information.

The Loci method connects certain objects with specific locations so that the individual may easily recall them (Solso et al, 2008). The Loci (location) method is used to help people memorize specific types of information (Bower in Solso et al, 2008). When people struggle to remember specific types of information, the Loci approach is used to help them. According to Dalgleish et al. (2013), the loci method can use visual imagery to connect things from the list that have just been studied with real locations that people are familiar with. As a result, by repeating activities to recall information using the loci method while visiting predefined sites, the memory of information will be sharper.

According to Li et al. (2021), the success of the loci method is dependent on the creation of a familiar environment that is used as a landmark (something that stands out or is easily seen as a pointer) or location paired with one or more items to remember when coding, as well as the mental ability to remember items. The loci approach helps aid the transition of abstract knowledge into concrete information, which is then more easily processed by the neurological system associated with memory.

The stages of implementing the loci method according to Stine (in Anshorulloh, 2008), include:

- select a place or location that is always remembered,
- select a fact or several information or items to be remembered,
- select elements or things associated with the locations utilized in remembering information,
- make visual representations that tie information to characteristics of the area or location, and
- show the visuals numerous times a day for three or four days.

As stated by Kaplan and Wolf (2017), the loci method necessitates a clear reference to the location of the things to facilitate their discovery. According to Tilley (2016), there are several rules to remember using the loci method, including 1) not using the same two objects, 2) not putting objects in a zigzag manner, and 3) having confidence in one's ability to visualize familiar locations can make it easier to remember using the loci method.

Li et al (2021) used two groups in their experimental study of the loci method: the experimental group and the control group. The experimental group was assessed with four different types of cognitive tasks that lasted two hours for the pretest and posttest, whereas the training session lasted 20 days, four consecutive weeks, and five days per week. Spend 30 minutes every day in the training session performing working memory training utilizing the loci method. Meanwhile, the control group received no training during the 20 days. He divided the 20 days into two sessions, each lasting 10 days, in their experiment. The first ten days were spent introducing participants to the loci method and guiding them to recall the route of the place with some landmarks (hints), after which they were trained to remember items randomly related to these landmarks (hints). Landmarks can be serial numbers associated with each piece in the remembered object. Each route inside the place is learned and skilfully linked by participants based on individual experience, which is more likely to be remembered by oneself.

Furthermore, for the second session, each participant was directed to remember random items, wherein the first stage, participants were directed to remember 5 items for 90 seconds, and the items were immediately recorded on paper, then in the second stage, items that needed to be remembered were added again. 5 items became 10 items, and the duration used was also increased by 90 seconds to 180 seconds, and so on until all items were able to be remembered by participants well. If the participant can remember these items at a certain stage, then he can continue at the next stage, but if he has not been able to remember correctly, then he must complete the memorization of the items at the current stage.

Effectiveness of Loci Method to Improve Mathematics Learning Achievement

According to the findings of a study conducted by Retnoningsih (2015), the loci method affects the connection of items with geometric formulas for students of senior high school. This study is a real experimental design study with a pretest-posttest control group design. Research conducted by Ardika (2016) also showed that the mnemonic method proved effective for trigonometry learning in terms of memory and mathematics learning achievement on senior high school. Where from the results of his research also mentions that the mnemonic method can be used to increase student interest in learning and creativity when students make donkey bridges. And from the research, it was found that by giving treatment using the loci method, the overall memory of students increases and was included in the high category, and students' mathematics achievement was able to achieve scores above the minimum.

The loci method was used by repeatedly linking information (in the form of visual images) containing fraction material, velocity material, and discharge material in 37 pieces of material (items) in the form of posters connected to certain objects (which are different from each other) so that individuals can easily remember and understand the information and thus improve their mathematics achievement. More specifically, the loci method will improve mathematics achievement because students can understand information and remember information from each material in the poster and involve numeracy skills (interpreting mathematical numbers for problem-solving) in its implementation.

Problem of Study and Hypothesis

From the preceding information, the following research question can be derived: How effective the loci method was at improving mathematics learning achievement for elementary school students?. Therefore, the research hypothesis is: The loci method have a significant impact to improving mathematics learning achievement for elementary school students.

Method

Research Design

This research used an experimental research type, with the research design namely quasi-experimental design. Quasi-experimental research is an experimental research method that is not so strict in controlling the variables (Thyer, 2021). The sample in this quasi-experimental research was not determined randomly (Handley et al., 2018). In this quasi-experimental design, the researcher chose the form of the research, namely the one group pretest-posttest design. This research design was chosen to examine the causal relationship between the independent variable and the dependent variable by comparing pretest and posttest scores before and after treatment. The loci method variable is the independent variable in this study, and the mathematics achievement variable is the dependent variable. This study's design employed a single group of subjects with no comparison group. The research design is as follows (Knapp, 2016):

Table 2. One group pretest-posttest design

Pre-Test		Treatment		*Post-Test*
O_1	⟶	X	⟶	O_2

Where:

O_1 = *Pre-Test* (measurement of students mathematics achievement before being given treatment)

X = Treatment (giving treatment in the form of the Loci Method)

O_2 = *Post-Test* (measurement of students mathematics achievement after being given treatment)

Participants

The subjects in this study were students elementary school of grade 5th , totaling six students who were selected by non-random sampling, namely by taking research subjects that had conformity with predetermined characteristics. The criteria for selecting this subject include 1) Elementary school students in grade 5th, 2) having mathematics achievement that is included in the low classification based on the measurement results of the mathematics learning achievement test instrument for grade 5th , 3) willing to be involved in a series of experimental processes using the method loci. The research location is State Elementary School Krenceng 4 Kediri District, with the experimental room used, namely the library room of State Elementary School Kerenceng 4.

Data Collection Tool

Mathematics Learning Achievement Test

The data collection method in this study used the test method. The instruments used in this study were the mathematics learning achievement test instrument and the loci method treatment module instrument. The mathematics learning achievement test in this study uses a multiple choice question model where students choose one of 4 answer choices that are considered correct to answer the given math problem. Where in its manufacture the researchers were guided by the Package Book "Mathematics: For grade 5th" by Indrianti et al by Intan Pariwara Publisher and from the Book "Mathematics Teaching Materials" with Usaha Makmur Solo Publisher. The validity of the instrument was tested against four expert judgments, including two lecturers who were mathematicians and as well as two elementary school mathematicians.

In addition to the mathematics learning achievement test, the researcher also uses a research instrument in the form of the loci method treatment module which in its preparation is based on the theory and implementation procedures of the loci method from Solso et al (2008) and Li et al (2021). The instrument of the Loci Method Treatment Module is entitled "Loci Method Treatment Module to Improve Mathematics Learning Achievement grade 5th at state elementary school". The validity of the module was tested by an expert judgment expert in psychology with a specialization in education.

The researcher performed the content validity test to evaluate the instrument's validity. The Aiken V coefficient of 0.75 - 0.94 indicates that the grade 5th elementary school mathematics achievement test instrument has high validity based on the results of the content validity test of the fifth-grade mathematics learning achievement test instrument with calculations using the Aiken V index. Then, to test the content validity of the loci method treatment module with calculations using the Aiken V Index, the Aiken V coefficient of 0.67 - 1.00 means that the loci method treatment module instrument has high validity. In testing the reliability of the mathematics achievement test instrument, the researcher used the Split Half Spearman-Brown Formula. From 18 valid items, the results of the split half Spearman-Brown reliability calculation were 0.796.

The classification was utilized to categorize mathematics achievement scores on research subjects as high or low. The researcher's classification was based on the average score of mathematics achievement. The following are the findings of a descriptive analysis of the fifth-grade mathematics learning achievement test scores.

Table 3. Descriptive Statistics of Mathematics Learning Achievement Score

	N	Minimum	Maximum	Mean	Std. Deviation
Score of Mathematics Learning Achievement	22	3,00	16,00	9,23	3,74
Valid N (listwise)	22				

The average score on the mathematics achievement test is 9.23, according to the table above. The lowest and highest scores are 3 and 16, respectively. The standard deviation is also reported to be 3.74. The group norm is used to categorize mathematics accomplishment scores based on standard deviation and the average total score is shown below.

Table 4. Mathematics Learning Achievement Norms

Formula	Score Range	Classification
$X < 9.23$	3 – 9	Low
$9.23 \leq X$	10 – 16	High

According to the results of the mathematics learning achievement test instrument try-out of 22 students, 11 subjects have low learning achievement in mathematics, whereas 11 other subjects have high learning achievement.

Based on the difficulty level of each item calculated from the try-out results of the mathematics learning success test instrument, it was discovered that 9 items had a high or tough item difficulty level and 9 other items had a low or easy item difficulty level. In terms of item discrimination, there are 0 poor items, 10 unsatisfactory products, 4 quite good items, and 4 very good items. As a result, the 18 items on the mathematics achievement exam can be used in field data gathering.

The loci method theory proposed by Stine in Anshorulloh (2008), Halim (2012), and Li et al. was the foundation for the experimental design (2021). This trial design included six sessions over six days, with each treatment session lasting 120 minutes (two hours).

The normality and homogeneity tests were employed as precursor tests, as well as the paired sample t-test and Cohen's d effect size test as hypothesis tests. Because there were 50 subjects, the researcher utilized the Shapiro-Wilk normality test. The researcher was aided in conducting the Shapiro-Wilk normality test. In the Cohen's d effect size test, the size of the effect is expressed as a percentage. For Effect Size score classification, the following is a score classification table for the One Group Pretest Posttest according to Cohan in Dini, et al (2017).

Table 5. Cohen's d Effect Size Classification Score

Size	Interpretation
0 – 0,20	Weak effect
0,21 – 0,50	Modest effect
0,51 – 1,00	Moderate effect
>1,00	Strong effect

Furthermore, the classification in the form of percent according to Cohen in Becker (2000) is as follows.

Table 6. Classification of Cohen's d Effect Size Score in percent

Cohen Standard	*Effect Size*	Percentage
Big	2,0	81,1%
	1,9	79,4%
	1,8	77,4%
	1,7	75,4%
	1,6	73,1%
	1,5	70,7%
	1,4	68,1%
	1,3	65,3%
	1,2	62,2%
	1,1	58,9%
	1,0	55,4%
	0,9	51,6%
	0,8	47,4%
Medium	0,7	43,0%
	0,6	38,2%
	0,5	33,0%
	0,4	27,4%
	0,3	21,3%
Small	0,2	14,7%
	0,1	7,7%
	0,0	0%

Results

Description of the Loci Method Implementation

There are 6 subjects in this study, including MA, MI, MR, AR, SN, and VM. Based on the questionnaire given to all subjects, the subjects found it difficult with mathematics because it was difficult to remember mathematical material, especially the formulas and how to solve the problems. Before the experiment, all subjects had agreed to be the subject of the experiment by filling out the informed consent form. The implementation of the loci method was carried out in 6 sessions, including:

The First Session includes an introduction to the loci method, beginning with its knowledge, execution, and restrictions that each subject must follow when carrying out tasks utilizing the loci method later. All volunteers are willing and ready to participate in a series of experiments and follow all existing regulations. The subjects in this initial session paid close attention to the presentation and were certain that they would be pleased with the loci method. They believe that the loci method will help them remember mathematical formulas and material and improve their mathematics learning achievement based on the explanation provided. According to the MA subject, using the loci method can make learning and remembering mathematical formulas easier. The MI participant also stated that the loci approach can recall previously forgotten facts. Similarly, the topic of SN stated that the loci approach can help in remembering mathematical content and working on questions.

The Second Session includes activities to recall 13 items and their objects, the contents of which are to grasp and apply explanations relevant to implementation methods. The subjects performed admirably during this second session. Many subjects were quite eager in carrying out the exercises, especially understanding the material on the poster, but one subject fell asleep when explaining the material and several others joked about it. Researchers investigate these issues and attempt to revive activities by urging them to pay attention to the material's content, providing advice to help them recall the material, and conducting questions and answers to examine the material's content. In addition, the subject was still unable to build their visual picture so they still needed help from the researcher to provide ideas about the visual picture of the ongoing material. The subject was still hesitant to answer questions after the second session.

The Third Session contains activities to remember the 12 items and their objects which are a continuation of the previous item, the contents of which are to understand explanations related to the implementation procedures and apply what has been explained. In this third session, the subjects have started to memorize the flow of the activities, where they just need to continue the next 12 items from the 13 items that have been memorized previously. In this third session, several subjects started to dare to answer questions and create visual image ideas of the ongoing material. The subjects were very enthusiastic about exploring the material in the poster and it was rare to joke with their friends.

The Fourth Session includes activities to recall 12 items and their objects, which are a continuation of the preceding item, the contents of which are to comprehend and apply explanations related to implementation methods. The subjects were more comfortable with the flow of activities during the fourth session, and they became more passionate about carrying them out. In comparison to the previous session, all participants were able to answer questions confidently in this fourth session, however, some individuals were sluggish to respond. All individuals were allowed to offer their visual description of what was going on at the moment.

The Fifth Session includes activities that require students to recall random items of fractional content and record them on the given sheet. The length of memorizing all elements on the poster was shortened from 11 minutes to 8 minutes and then back to 5 minutes in this fifth session. This was done since the remaining time was spent remembering by joking and playing alone. So that when the length is shortened, all participants may implement the loci approach diligently and passionately. Some subjects were able to carry out activities to remember fractional items at random and record them correctly in this fifth session, but others were still constrained in carrying out activities where there was a miscommunication in writing random items and not fast enough in writing remembered items on the paper provided. Thus, in these circumstances, the researcher provided further instructions and advice on how to change the time limit. So that the topic can compensate for other subjects in the following step. In this fifth session, all subjects were, on average, able to complete three stages of remembering random items from the five previously planned stages. Although the whole subject has not been able to complete up to stage five, all items in the fractional material have been able to be remembered by the subject.

The Sixth Session includes activities to recall random items of velocity and discharge material and report these items on the given page. Because the flow of activities in the sixth session was the same as the flow in the fifth session, the subjects had already learned it. The distinction is that the subject to memorize is speed and discharge, and the sixth session concludes with a quiz session. All subjects were able to carry out tasks easily, and all were able to complete all phases of memorizing, specifically three stages of memorizing random items of speed and discharge.

Analysis of Data

The following is an explanation of the data on mathematics achievement scores before and after being given treatment using the loci method for six students. The presentation of the data can be seen in the following.

Table 7. Scores of Pre-test and Post-test Results of Grade 5th Mathematics Achievement

No.	Initial	***Pre-test***	Category	***Post-test***	Category
1.	MA	9	Low	12	High
2.	MR	8	Low	10	High
3.	MI	7	Low	8	Low
4.	AR	7	Low	12	High
5.	SN	9	Low	14	High
6.	VM	8	Low	13	High

According to Table 7, the six participants received a pretest score ranging from 7 to 9, with the overall category score being the lowest. Following treatment with the loci method methodology, the results obtained from six participants ranged from 8 to 14, with subjects MA, MR, AR, SN, and VM scoring in the high category, but MI subjects scoring in the low category.

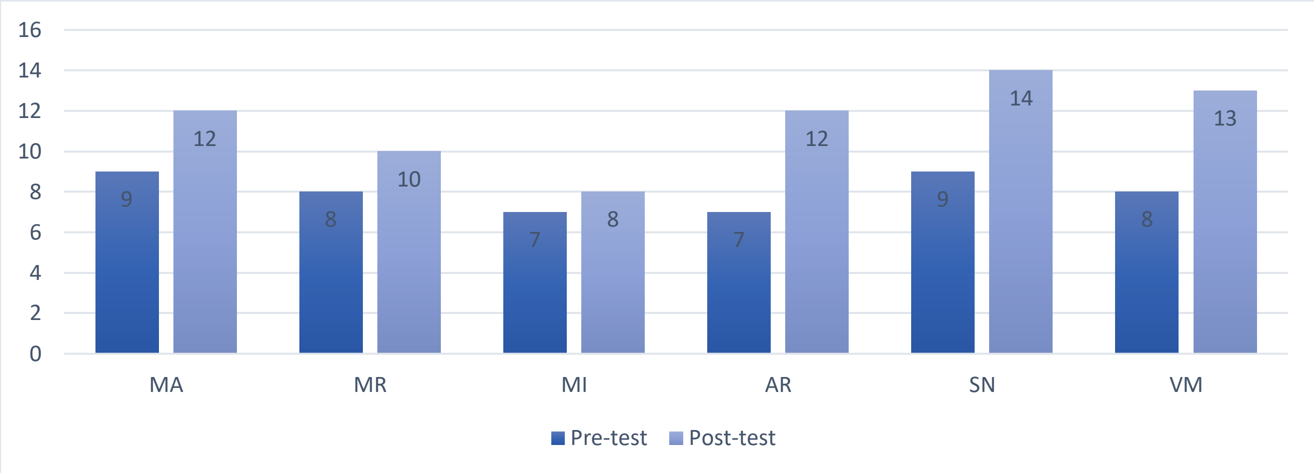


Figure 1. Bar Chart of Pre-test and Post-test Scores of Class V Mathematics Learning Achievement

Based on Figure 1 above, it is known that there is an increase between the pretest score and the posttest score with a different increase in each subject.

Table 8. Changes in Mathematics Learning Achievement Score

No.	Name Initial	***Pretest***	***Posttest***	Change	Percentage (%)
1.	MA	9	12	+3	33,33
2.	MR	8	10	+2	25,00
3.	MI	7	8	+1	14,29
4.	AR	7	12	+5	71,43
5.	SN	9	14	+5	55,56
6.	VM	8	13	+5	62,50

The pretest and posttest scores for each subject are provided in the table above, along with the percentage change in each subject's score and the amount by which the score increased between the pretest and posttest.

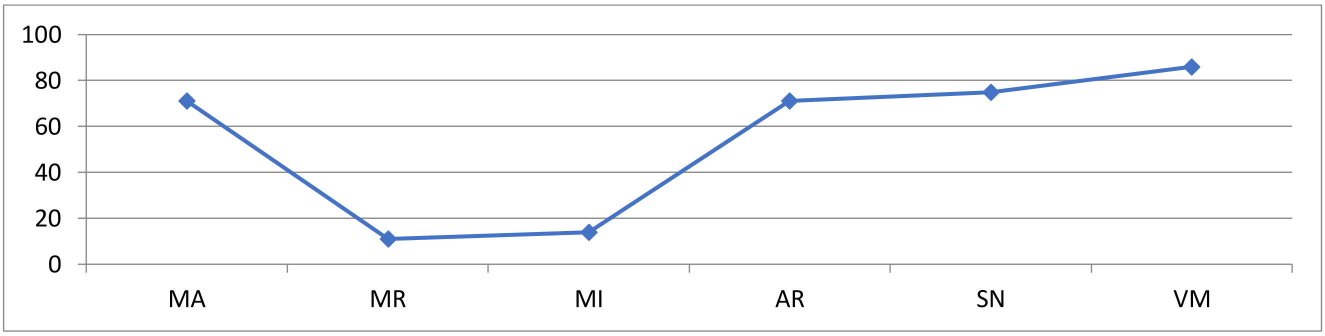


Figure 2. Line Diagram of Changes in Mathematics Learning Achievement Scores (in Percentage)

The picture above is a graph of the percentage change score in each subject. It is known that the percentage is very different from one subject to another.

Hypothesis Testing

Before testing the hypothesis, the pretest and post test data will be checked whether they have normality distribution and homogeneity.

Table 9. Significance of Normality Test

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre Test	,202	6	,200*	,853	6	,167
Post Test	,258	6	,200*	,940	6	,659

According to the calculations shown in the above table, the pretest data have a significance of 0.167, where the p-value > 0.05. The pretest results for grade 5th mathematics achievement can thus be interpreted as having a normal distribution. And for post-test data with a p-value of 0.659 > 0.05. Therefore, it can be inferred that the post-test results on grade 5th students' math achievement are similarly normally distributed. Thus, the two data can be used to test the paired sample t-test.

Table 10. Significance of Homogeneity Test

Test of Homogeneity of Variances					
		Levene Statistic	df1	df2	Sig.
Skor Test	Based on Mean	3,673	1	10	,084
	Based on Median	1,623	1	10	,231
	Based on Median and with adjusted df	1,623	1	6,144	,249
	Based on trimmed mean	3,379	1	10	,096

Based on the results of the homogeneity test above, it is known that the variation of the two samples has a significance of 0.096 > 0.05, it can be concluded that the variance of the two samples in the pretest and post-test scores of class V mathematics learning achievement is homogeneous or the same.

Hypothesis testing using paired sample t-test. The paired sample t-test can be used to see if there is a difference in the sample mean between the two conditions before and after treatment. The paired sample t-test calculation yielded the following results.

Table 11. Standard Deviation Calculation Results

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	7,5000	6	,83666	,34157
	Posttest	11,5000	6	2,16795	,88506

In the table above, it is known that the average value of 6 subjects in the pretest is 7.5 while the average value of the post-test is 11.5. Then it is also known that the standard deviation of the pretest is 0.34 while the standard deviation of the posttest is 0.89.

Table 12. Correlation Significance of Pretest & Posttest

Paired Samples Correlations				
		N	Correlation	Sig.
Pair 1	Pretest & Posttest	6	-,055	,917

The correlation between pretest and posttest has a reasonably significant correlation of 0.917 in the table above, with the opposite direction of the relationship.

Table 13. The Significance of the Paired Sample t-test

Paired Samples Test									
		Paired Differences					**t**	**df**	**Sig.**
		Mean	**Std. Deviation**	**Std. Error Mean**	**95% Lower**	**95% Upper**			
Pair 1	Pretest - Posttest	-4,00000	2,36643	,96609	-6,48342	-1,51658	-4,140	5	,009

Based on the foregoing calculations, a significance of 0.009 was found where the p-value (0.009) = 0.05. As can be observed, there is a distinction between the pretest and the posttest. As a result, the best effective way to increase the mathematics learning success of primary school students in class V can be inferred.

The Test of Cohen's d Effect Size

Based on the classification of Effect Size scores (Cohen, 1992), it was found that the use of the loci method technique in improving mathematics learning achievement for fifth-grade elementary school students at State Elementary School Krenceng 4 had a high effect (Strong effect) of 1.84 or 77, 4%.

Discussion and Conclusion

The loci method has high efficacy in enhancing mathematics learning achievement of fifth-grade elementary school students at State Elementary School Krenceng 4, Kediri District, according to the study's findings. In this study, the researcher administered a pretest and a posttest before and after treatment to determine the difference in grade 5th mathematics achievement scores, which could be used to determine the effectiveness of the loci method on fifth-grade students' mathematics achievement.

Before using the loci method, the mathematics learning achievement of the fifth-grade subjects at State Elementary School Krenceng 4 was still relatively low. This can be seen from the results of the pre-test on six subjects, namely MA, MR, MI, AR, SN, and VM subjects. The subjects had been given learning by the researchers using the usual method used by the teachers before the researchers gave the subjects a pretest mathematics learning achievement test. After being given a mathematics achievement test, it was found that all six participants received scores in the low category with an average score of 7.5.

The subjects claimed that the pretest was difficult to complete since it was difficult to remember the mathematical formulas and understand the material provided during class learning. According to Grootenboer and Marshman (2015), mathematics is frequently regarded as a difficult and boring subject. According to Sun et al (2018), mathematics material was difficult to understand and formulas were difficult to memorize. Meanwhile, the ability to recall is affected by the method chosen (Mukherji & Albon, 2018).

The subjects' learning method has been limited to listening to the teacher explain the topic in front of them, with no alternative methods employed to supplement or enhance existing learning methods. The subjects thought that the previous strategy had failed to make them happy about mathematics and improve their mathematics learning achievement. Pupils might be glad to learn well when the learning approach utilized is entertaining and tailored to their needs, since this can later assist students to concentrate and understand the material provided (Dempo & Seli, 2016). Nganji (2018) also believes in his theory that when students build their knowledge, it is better than when the knowledge is handed to them in a ready-made shape by their teacher. In other words, when students build their knowledge, they will be better able to understand it. According to Hmelo-Silver (2012), memory is required in recycling knowledge because it is used to obtain new knowledge or answer difficulties. So that when kids learn mathematical content, it is easier for them to memorize formulas, allowing them to thrive in mathematics (Su et al., 2016)

The loci method improved the mathematics achievement of fifth-grade subjects at State Elementary School Krenceng 4. This is evident from the post-test findings of six subjects: MA, MR, MI, AR, SN, and VM. Five of the six subjects scored in the high range, while one scored in the low range. The subject's mathematics learning achievement increased from 7.5 (low category) to 11.5 (high category). According to Ni and Hasan (2019), the mnemonic method (which includes the loci method, dependent word system method, keyword method, acronym method, and acrostic method) can assist students to maximize their memory so that they can recall the formulas utilized in mathematics appropriately.

Following treatment with the loci method, the subjects were enthusiastic about employing the loci method and believed that doing so would improve their mathematics achievement. The subjects in this study thought mathematics was tough, but after being treated with the loci method, they claimed they could understand the content extremely well since the loci approach helped students' memory in retaining even difficult material. According to Solso et al. (2008), the loci technique relates information on specific things with specific locations with the hope that the respondent will recall the information more easily.

This is as influential as the research conducted by Ardika (2016) that the memory and mathematics learning outcomes of high school students experienced improvement after using the mnemonic method (which consists of the loci method, dependent word system method, keyword method, acronym method, and acrostic method), which is indicated by a change in scores on student learning outcomes tests and student memory questionnaire data scores before and after the treatment. According to the study's findings, 24 students from all subjects met the high criteria, 1 student met the very high criteria, and 3 students met the sufficient criteria. The learning outcomes of the subjects in the study after participating in learning using the mnemonic method revealed that all students succeeded well, where the mnemonic method was effectively applied, as evidenced by the completion of 89.29% of students in fulfilling the minimum score determined by the school is 78, with an average score of 87.32. The survey also revealed that all subjects were enthusiastic about taking part in the experiment and actively participated in the discussion by asking questions.

The loci method is a successful strategy for increasing primary school students' mathematics learning achievement in grade 5th. In the Cohen's d effect size test, the results were 1.84, the score belongs to the category that has a strong effect of 77.4%. This is consistent with Solso et al. (2008)'s theory that the loci method produces adequate outcomes for serial learning. In this study's implementation of the loci method, a material contained in a poster affixed to the first object will be continued to the material on the poster in the next object with a certain serial number until the subjects have known and remembered the entire material in the poster in the experimental room. Serial learning is a type of learning that systematically provides linguistic features from one sequence to another to memorize and remember (Jones & Macken, 2015).

Furthermore, McCabe (2015) claims that of the entire mnemonic way of remembering methods, the loci method is the oldest and most successful method of remembering, because only the loci method is used by linking specific items or information with things in place around the individual. According to Cozolino (2017), the Loci method is closely related to the use of the cortex in the left and right hemispheres, where the loci method combines the power of imagination and sensuality with the accurate ordering of places, where imagination and sensuality is a right brain function and accurate ordering of places is a left brain function.

This loci method is used frequently for people to recall certain information more readily (Solso et al, 2008). This is also related to the theory of memory, where he stated that certain information that is processed repeatedly can last longer in the cerebrum and stay in Long Term Memory (LTM) compared to information without being given repetition will only be in Short Term Memory and will be more easily replaced by other incoming information. Similarly, Williams et al. (2021) stated that the loci approach is superior for remembering since it uses a brain ability, specifically the hippocampus, which allows memories to be remembered stronger and last longer.

A mathematics achievement that requires comprehension will be able to grow if the concept of numeracy is used in its implementation, which is consistent with the concept of the loci method itself. Whereas boosting mathematics learning achievement necessitates the use of memory to access information or reuse knowledge stored in the brain connected to the content asked in the questions on learning achievement exams. According to Zull (2012), memory is required for recycling knowledge since it is utilized to obtain new knowledge or address difficulties. Moreover, the loci method can help to improve and develop this memory.

As stated by Qureshi et al. (2014), the loci method is used more effectively than other mnemonic methods because it encourages the subject to present an image of an object that will be remembered in his mind, and the loci method is used effectively in remembering related information and can be used in remembering faces, numbers, and lists of words. According to Brancucci (2012), the effectiveness of the loci technique is due to the usage of brains connected to spatial learning rather than brain anatomy and intellect. According to Palvio (2014) explanation, students of varied intelligence and brain architectures can employ the loci method together. According to Gross et al. (2016), the loci method is the best mnemonic strategy for word recall.

Previous research by Retnoningsih (2015), found that the loci method had an influence on the association of spatial formula objects in mathematical topics. The findings of hypothesis testing show that the difference in mean in the experimental group is 13.667, whereas the difference in mean in the control group is just 1.0. As a result, the average value of the association of mathematical geometrical formula objects for students taught using the loci approach was greater than the average of the associations for students not taught using the loci method. In other words, the loci technique may be inferred to be a successful strategy for improving mathematics learning achievement.

The study's findings show that the loci method is highly successful in enhancing mathematics learning achievement in fifth-grade elementary school students. However, several flaws were discovered in this study, where it was felt that the research subjects did not pay attention to the situation and conditions in the field because the duration of two hours in each treatment session had not been adjusted to the normal and normal conditions of elementary school students in grade 5th in learning. Additionally, the time allotted needs to be modified to account for how long each instructor typically spends teaching math to children.

In addition to the length of the treatment, the offered posters could be more suited to the age of the participants, who are in grade 5th of an elementary school and prefer pictures of certain cartoon characters. To get more trustworthy data, direct interviews with the individuals are required to supplement difficulties in the field. The results would also be more accurate and the study would utilize more individuals if it were performed utilizing a research method that allowed for the inclusion of a control group as a comparison. This can provide data for future research.

Recommendations

Based on the research that has been done, The researcher's suggestions to educators can add or modify existing learning methods with the loci method; it is hoped that the loci method technique module can be used to help students improve their mathematics achievement. It is advised that the school conduct mathematics training utilizing the loci method, the implementation methods for which are specified in a module that is tailored to the context and conditions in the field. The researcher suggests several things for future research, including 1) Using the loci method with a daily duration that is adjusted to students at a certain level and a longer treatment period as in previous long-term studies, 2) the use of poster media or other learning media must be adjusted to the attractiveness of students, for example, by providing pictures of their favorite cartoon characters, 3) can further deepen the problem data in the field through direct interviews with the subjects, 4) lastly, future researchers can opt to conduct a study that includes a control group as a comparison to ensure more reliable results, as well as subjects that are also replicated.

Acknowledgements

Thanks to the Faculty of Psychology, Malang State University and Elementary School 4 Krenceng, Kediri, East Java as research location.

References

Andersson, C., & Palm, T. (2017). The impact of formative assessment on student achievement: A study of the effects of changes to classroom practice after a comprehensive professional development programme. *Learning and Instruction*, *49*, 92–102.

Anshorulloh, R. (2008). Efektivitas metode mnemonik dalam meningkatkan daya ingat siswa pada mata pelajaran sejarah di MTs Persiapan Negeri Kota Batu (The effectiveness of the mnemonic method in improving students' memory in history subjects at State MTs Preparation, Batu City). *Skripsi*. Fakultas Psikologi, Universitas Islam Negeri Malang.

Ardika, Y. (2016). Efektivitas metode mnemonik dalam meningkatkan daya ingat dan hasil belajar matematika siswa SMK Kelas X (The effectiveness of the mnemonic method in improving memory and mathematics learning outcomes for students class X, Vocational High School). *Jurnal Matematika Kreatif-Inovatif*, 7 (1), 66-73 , https://doi.org/10.15294/kreano.v7i1.5006.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st century skills*. Springer.

Brancucci, A. (2012). Neural correlates of cognitive ability. *Journal of Neuroscience Research*, *90*(7), 1299–1309.

Cohen, J. (1992). A power primer. Psychol. Bull. 112, 155–159. doi: 10.1037/0033- 2909.112.1.155

Cohen, P. C. (2016). *A calculating people: The spread of numeracy in early America*. Routledge.

Cozolino, L. (2017). *The neuroscience of psychotherapy: Healing the social brain*. WW Norton & Company.

Dalgleish, T., Navrady, L., Bird, E., Hill, E., Dunn, B. D., & Golden, A.-M. (2013). Method-of-loci as a mnemonic device to facilitate access to self-affirming personal memories for individuals with depression. *Clinical Psychological Science*, *1*(2), 156–162.

Dembo, M. H., & Seli, H. (2016). *Motivation and learning strategies for college success: A focus on self-regulated learning*. Routledge.

Dian. (2022). Kemendikbudristek harap skor PISA Indonesia segera membaik (Kemendikbudristek hopes Indonesia's PISA score will improve soon). Radio Edukasi (Online), (https://radioedukasi.kemdikbud.go.id/read/3341/kemendikbudristek-harap-skor-pisa-indonesia-segera-membaik.html), diakses 1 Agustus 2022.

Grootenboer, P., & Marshman, M. (2015). *Mathematics, affect and learning*. Springer.

Gross, A. L., Brandt, J., Bandeen-Roche, K., Carlson, M. C., Stuart, E. A., Marsiske, M., & Rebok, G. W. (2014). Do older adults use the method of loci? Results from the ACTIVE study. *Experimental Aging Research*, *40*(2), 140–163.

Han, S., Capraro, R., & Capraro, M. M. (2015). How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement. *International Journal of Science and Mathematics Education*, *13*(5), 1089–1113.

Handley, M. A., Lyles, C. R., McCulloch, C., & Cattamanchi, A. (2018). Selecting and improving quasi-experimental designs in effectiveness and implementation research. *Annual Review of Public Health*, *39*, 5–25.
Hmelo-Silver, C. E. (2012). Learning theories and problem-based learning. In S. Bridges, C. McGrath, & T. L. Whitehill (Eds.), *Problem-based learning in clinical education* (pp. 3–17). Springer.
Huang, T.-H., Liu, Y.-C., & Chang, H.-C. (2012). Learning achievement in solving word-based mathematical questions through a computer-assisted learning system. *Journal of Educational Technology & Society*, *15*(1), 248–259.
Jones, G., & Macken, B. (2015). Questioning short-term memory and its measurement: Why digit span measures long-term associative learning. *Cognition*, *144*, 1–13.
Kaplan, A., & Wolf, C. (2017). *The conduct of inquiry: Methodology for behavioral science*. Routledge.
Kauffman, H. (2015). A review of predictive factors of student success in and satisfaction with online learning. *Research in Learning Technology*, *23*.
Khalalia, R. (2015). The relationship between academic self-concept, intrinsic motivation, test anxiety, and academic achievement among nursing students: Mediating and moderating effects. *Nurse Education Today*, *35*(3), 432–438.
Knapp, T. R. (2016). Why is the one-group pretest–posttest design still used? *Clinical Nursing Research*, *25*(5), 467–472.
Legge, E. L., Madan, C. R., Ng, E. T., & Caplan, J. B. (2012). Building a memory palace in minutes: Equivalent memory performance using virtual versus conventional environments with the Method of Loci. *Acta Psychologica*, *141*(3), 380–390.
McCabe, J. A. (2015). Location, location, location! Demonstrating the mnemonic benefit of the method of loci. *Teaching of Psychology*, *42*(2), 169–173.
McLean, L., & Connor, C. M. (2015). Depressive symptoms in third-grade teachers: Relations to classroom quality and student achievement. *Child Development*, *86*(3), 945–954.
Mirzeoglu, A. D. (2014). The effects of peer teaching on the university students achievements in cognitive, affective, psychomotor domains and game performances in volleyball courses. *Educational Research and Reviews*, *9*(9), 262–271.
Mukherji, P., & Albon, D. (2018). *Research methods in early childhood: An introductory guide*. SAGE.
Nganji, J. T. (2018). Towards learner-constructed e-learning environments for effective personal learning experiences. *Behaviour & Information Technology*, *37*(7), 647–657.
Ni, L. B., & Hassan, N. A. (2019). The use of mnemonic and mathematical mnemonic method in improving historical understanding. *International Journal of Educational and Pedagogical Sciences*, *13*(2), 93–97.
Palvio, A. (2014). Intelligence, dual coding theory, and the brain. *Intelligence*, *47*, 141–158.
Papadopoulos, I. (2013). Using calculators for assessing pupils' conceptualization on place-value. *International Journal of Mathematical Education in Science and Technology*, *44*(4), 523–544.
Peek, R. (2016). Exploring learner autonomy: Language learning locus of control in multilinguals. *International Journal of Multilingualism*, *13*(2), 230–248.
Pressley, M., Levin, J. R., & McDaniel, M. A. (2014). Remembering versus inferring what a word means: Mnemonic and contextual approaches. In M. G. McKeown & M. E. Curtis (Eds.), *The nature of vocabulary acquisition* (pp. 107–127). Psychology Press.
Qureshi, A., Rizvi, F., Syed, A., Shahid, A., & Manzoor, H. (2014). The method of loci as a mnemonic device to facilitate learning in endocrinology leads to improvement in student performance as measured by assessments. *Advances in Physiology Education*, *38*(2), 140–144.
Retnoningsih, O. T. D. (2015). Pengaruh permainan metode loci terhadap asosiasi objek rumus bangun ruang pada remaja di SMPN 5 Madiun (The effect of the loci method game on the association of objects with geometric formulas in adolescents at SMPN 5 Madiun). *Skripsi* . Madiun: Fakultas Psikologi Universitas Katolik Widya Mandala.
Riccomini, P. J., Smith, G. W., Hughes, E. M., & Fries, K. M. (2015). The language of mathematics: The importance of teaching and learning mathematical vocabulary. *Reading & Writing Quarterly*, *31*(3), 235–252.
Rosa, N. (2022). Yang ditunggu, ini hasil lengkap asesmen nasional 2021 (What's awaited, here are the complete results of the 2021 national assessment). Detik Edu (Online), (https://www.detik.com/edu/edutainment.d-6011654/yang-ditunggu-ini-hasil-lengkap-asesmen-nasional-2021), accessed 7 Agustus 2022.
Rowan-Kenyon, H. T., Swan, A. K., & Creager, M. F. (2012). Social cognitive factors, support, and engagement: Early adolescents' math interests as precursors to choice of career. *The Career Development Quarterly*, *60*(1), 2–15.
Salim, M., & Mujtahidah, N. (2020). Penerapan Kurikulum 2013 Revisi 2018 dalam Meningkatkan Prestasi Belajar Siswa: Studi Multi Situs di SMP Raden Fatah Batu dan MTs. Ihyaul Ulum Dukun Gresik (Implementation of the 2013 Revised 2018 Curriculum in Improving Student Achievement: Multi-Site Study at Raden Fatah Batu, Junior High School and MTs. Ihyaul Ulum Shaman Gresik). *Al-Idaroh: Jurnal Studi Manajemen Pendidikan Islam, 4*(1), 86-107. https://doi.org/10.54437/alidaroh.v4i1.146
Sasson, I., & Cohen, D. (2013). Assessment for effective intervention: Enrichment science academic program. *Journal of Science Education and Technology*, *22*(5), 718–728.
Shrout, P. E., & Lane, S. P. (2012). Psychometrics. In M. R. Mehl & T. S. Conner (Eds.), *Handbook of research methods for studying daily life* (pp. 302–320). The Guilford Press.
Sriyatun, S. (2020). PISA dan TIMSS sebagai acuan AKM (PISA and TIMSS as AKM reference). Gurusiana (online), (http://www.gurusiana.id/read/sitisriyatun/article/pisa-dan-timss-sebagai-acuan-akm-3711194), accessed pada 1 Agustus 2022.
Sternberg, R. J. (2012). What is mathematical thinking? In R. J. Sternberg & T. Ben-Zeev (Eds.), *The nature of mathematical thinking* (pp. 319–334). Routledge.
Stoet, G., & Geary, D. C. (2018). The gender-equality paradox in science, technology, engineering, and mathematics education. *Psychological Science*, *29*(4), 581–593.
Su, H. F., Ricci, F. A., & Mnatsakanian, M. (2016). Mathematical teaching strategies: Pathways to critical thinking and metacognition. *International Journal of Research in Education and Science*, *2*(1), 190–200.

Sun, Z., Xie, K., & Anderman, L. H. (2018). The role of self-regulated learning in students' success in flipped undergraduate math courses. *The Internet and Higher Education*, *36*, 41–53.

Swasty, R. (2022). Hasil asesmen nasional 2021: Literasi numerasi SD butuh perhatian serius (Elementary numeracy literacy needs serious attention). Medcom.id (Online), (https://www.medcom.id/pendidikan/news-pendidikan/ybJr79Ab-hasil-asesmen-nasional-2021-literasi-numerasi-sd-butuh-perhatian-serius), accessed 7 Agustus 2022.

Syanthi, Hiunata, C., Sherly, Claudia, J. (2016). Pengaruh metode loci terhadap kemampuan mengingat pelajaran ipa pada siswa Kelas V SD (The effect of the loci method on the ability to remember science lessons in fifth grade elementary school students). *Psibernetika*, 9 (1), 67-77.

Thyer, B. A. (2012). *Quasi-experimental research designs*. Oxford University Press.

Tilley, C. (2016). *Body and image: Explorations in landscape phenomenology*. Routledge.

Williams, S. E., Ford, J. H., & Kensinger, E. A. (2022). The power of negative and positive episodic memories. *Cognitive, Affective, & Behavioral Neuroscience*, *22*, 869–903.

Willingham, D. T. (2021). *Why don't students like school?: A cognitive scientist answers questions about how the mind works and what it means for the classroom*. John Wiley & Sons.

Zimmerman, B. J. (2013). Theories of self-regulated learning and academic achievement: An overview and analysis. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic achievement* (pp. 1–36). Routledge.

Zubaidah, N. (2021). Asesmen nasional hanya akan diikuti siswa Kelas 5, 8 dan 11 (The national assessment will only be followed by Grade 5, 8 and 11 students). SindoNews.com (Online), (https://edukasi.sindonews.com/read/314200/212/asesmen-nasional-hanya-akan-diikuti-siswa-kelas-5-8-dan-11-1611637308)

Zull, J. E. (2012). *From brain to mind: Using neuroscience to guide change in education*. Stylus Publishing.

JMETP
Journal for the Mathematics Education and Teaching Practices, 3(2), 87-99, Dec 2022
e-ISSN: 2717-8587
dergipark.org.tr/jmetp

Young Wise Publishing
youngwisepub.com
gencbilgeyayincilik.com © 2022

Research Article

Mathematical thinking processes for the pythagorean theorem of the secondary school students[1]

Esra Akarsu Yakar[2] and Suha Yilmaz[3]

Department of Mathematics and Science Education, Buca Faculty of Education, Dokuz Eylul University, Izmır, Turkiye

Article Info

Received: 30 October 2022
Accepted: 25 December 2022
Available online: 30 Dec 2022

Keywords:
Geometric thinking
Mathematical thinking
The three worlds of mathematics

Abstract

In this study, the mathematical thinking processes on geometry of 6th, 7th and 8th grade students who have the same geometric thinking levels were examined. Two students from each grade level were selected for the study. The geometric thinking levels of the students were determined as the third level. In addition, the algebraic thinking levels of the students were discussed. The three worlds of mathematics was used in the research. The mathematical thinking processes of the students were examined in terms of the embodied world, the proceptual world and the formal world. The Pythagorean Theorem was chosen as the geometry subject. Two-stage semi-structured interviews were conducted with the students. In the first part of the interviews, the verbal expression of the Pythagorean Theorem was directed to the students. In the second part, an activity was presented for them to discover the theorem in a real-life situation. As a result, while the students had difficulty in explaining the theorem in the verbal expression, they were able to express it more easily in a real-life situation. 7th and 8th grade students were more successful than 6th grade students in demonstrating the processes of the three worlds of mathematics.

To cite this article

Akarsu Yakar, E. & Yılmaz, S. (2022). Mathematical thinking processes for the pythagorean theorem of the secondary school students. *Journal for the Mathematics Education and Teaching Practices, 3*(2), 87-99.

Introduction

Students' judgments about concepts in mathematics are related to mathematical thinking (Doğan & Güner, 2012). When the literature is examined, mathematical thinking is defined by some researchers as generalization, induction, deduction, logical thinking, using symbols, abstract thinking (Alkan & Bukova Güzel, 2005; Burton, 1984; Henderson et al., 2002; Liu, 2003; Liu & Niess, 2006; Mason, Burton & Stacey, 2010; Mubark, 2005; Polya, 1945; Stacey, 2006; Tall, 2002; Yeşildere & Türnüklü, 2007); it is defined by some researchers as the process of formation of concepts in the mind (Schoenfeld, 1992; Tall, 2006). Mathematical thinking is an important component in the concept formation process. Therefore, it is also important for mathematics teaching. During mathematical thinking, mathematical processes such as reasoning, problem solving and estimation are applied (Henderson et al., 2002). Mathematical thinking is individual. It is the process of creating new concepts within the knowledge structures of individuals. In other words, it is the act of adapting the new concepts encountered by the individual in his/her mind. It is the ability of an individual to use mathematical actions in the process of learning concepts. It is also the ability of the individual to explain the problem-solving processes. Studies that focus on the process in mathematical thinking (Dreyfus, 2002; Freudenthal, 1973; Tall, 1995) have examined mathematical thinking developed in concept formation. According to Bal & Dinç Artut (2020),

[1] This research was produced from the first author's doctoral thesis under the supervision of the second author.
[2] Corresponding Author: Ministry of National Education, Kocaeli, Türkiye, E-mail: es.akarsu@gmail.com, ORCID No: 0000-0002-4090-6419
[3] Dokuz Eylul University, Buca Faculty of Education, Izmir, Türkiye. E-mail: suha.yilmaz@deu.edu.tr, ORCID: 0000-0002-8330-9403

doing mathematics involves the application of operations and symbolic transformations. Mathematical thinking is more complex. It is also the ability to think in daily life.

Geometric thinking, which is part of mathematical thinking, is an individual's process of perceiving and interpreting shapes. The individual who encounters geometric concepts for the first time tries to make sense of them in his/her mind, analyzes the properties of shapes, divides shapes into groups. In short, he/she creates structures in his/her mind for geometric concepts and relationships. This process is the geometric thinking process. In geometric thinking, there is a transition from the physical world to the abstract world. According to Gündoğdu Alaylı (2012), geometric relations and the structuring of mathematical relations are related. All levels in mathematical thinking processes are also valid for geometric thinking.

In the literature (Alyeşil, 2005; Bobango, 1988; Fidan, 2009; Gündoğdu Alaylı, 2012; Olkun, Toluk & Durmuş, 2002; Özcan, 2012; Tuluk & Dağdelen, 2020, Usiskin, 1982) it is seen that the Van Hiele approach is generally based on the development of geometric thinking. Van Hiele (1986) states that geometric thinking in children occurs in five stages. These are visual level, analytical level, informal deduction (experience-based inference), formal deduction (inference) and the most advanced level. According to this theory, thinking proceeds sequentially. According to the first level, individuals can say the names of the shapes and make measurements. At the second level, the individual analyzes and explains the properties of shapes. At the third level, they can compare and classify shapes. At the fourth level, the individual can perform abstract thinking and make geometric proofs with the help of axioms. At the fifth level, he/she can put forward his/her own theorems. According to the studies in the literature (Breen, 2000; Gündoğdu Alaylı, 2012; Fidan, 2009; Fuys, 1985; Karakarçayıldız, 2016; Mistretta, 2000; NCTM, 2000; Özcan, 2012; Van de Walle, 2004), middle school students generally perform geometric thinking between the first and third levels.

In this study; the mathematical thinking processes of the students were examined with the theoretical framework of the three worlds of mathematics. The three worlds of mathematics deal with mathematical thinking in three phases. These phases are assumed to occur sequentially (Tall, 2007). Each thinking world represents the transition from concrete thinking to abstract thinking. According to this theory, the first stage of thinking is the embodied world. In this thinking world, the individual expresses the concrete properties of objects. The visual-spatial properties of the objects are in the foreground (Jukić & Brückler, 2014). The second stage of thinking is the proceptual world. In this world of thinking, there is concept thinking during operation. Expressing the concept with symbols includes algebraic thinking. The individual expresses the concept symbolically as a result of repetitive actions. The third stage of thinking is the formal world. We can find the proof here. The individual expresses the concepts with his/her own sentences, creates his/her own definitions of concepts as a result of mathematical proof.

Algebra and geometry are two related branches of mathematics. In the theoretical framework of the three worlds of mathematics, it is important to create symbolic expressions. Geometry topics also include topics that involve algebraic expression creation processes. One of them is the Pythagorean Theorem which is a subject where students need to use their knowledge of both geometry and algebra. According to Ramdhani & Suryadi (2018), students have difficulty in solving problems when they cannot comprehend the relationship between concepts in geometry and the Pythagorean Theorem. In this study, we focused on the Pythagorean Theorem which is among the 8th grade achievements in the Curriculum of the Ministry of National Education of the Republic of Turkey (MoNE, 2018). Therefore, examining the concept formation skills of 6th and 7th grade students about this theorem constitutes the originality of the research. In the study, the mathematical thinking processes of six secondary school students who have the same geometric thinking level were examined. The students were in 6th,7th and 8th grades. According to the theory of the three worlds of mathematics at the secondary school level, students cannot be expected to fully realize the formal world dimension. However, it is thought that students will be able to express the proof processes, albeit at a simple level. It is also envisaged that they can use their own definitions while expressing the concepts. This dimension was also considered in the study. It is thought that students have difficulties in transitioning from concrete thinking to abstract thinking. This idea forms the basis of the research. When the literature was examined, it was seen that the mathematical thinking processes of individuals were generally examined in terms of different theoretical frameworks such as APOS (Açan, 2015; Açıl, 2015; Akarsu, 2022; Hannah, Stewart & Thomas, 2016; Martínez-Planella & Triguerosb, 2019; Mudrikah, 2016), SOLO Taxonomy (Bağdat & Saban, 2014; Chan et al., 2002; Groth ve Bergner, 2006; Köse, 2018; Lucas & Mladenovic, 2008) and RBC Theory (Tsamir & Dreyfus, 2002; Türnüklü & Özcan; 2014; Yeşildere, 2006). When the studies which include three worlds of mathematics (Hannah, Stewart & Thomas, 2016; Jukić & Brückler, 2014; Kashefi, Ismail & Yusof, 2010; Kidron, 2008; Tall, Lima & Healy, 2014; Vandebrouck, 2011) were examined, no study was found that dealt with the theory of the three worlds of mathematics and geometric thinking together. Therefore, examining the theoretical framework of the three worlds of mathematics within the field of learning geometry emphasizes the importance of this research.

Method

Research Model

The research was designed with mixed pattern model. Quantitative and qualitative patterns were used together. Quantitative design was used to determine the participants of the study according to their geometric thinking levels. The singular screening method was determined as the quantitative research pattern. Qualitative design was used to determine students' mathematical thinking skills. The case study was chosen as a qualitative research pattern. Mathematical thinking skills of students were determined by semi-structured interview technique.

Participants, Sampling and Data Analysis

Purposive sampling method was used to determine the participants of the study. The criterion here is that students' geometric thinking levels are at the third level. In addition, considering that the algebraic thinking levels of the students may affect their mathematical thinking skills in geometry, the algebraic thinking levels of the students were examined.

"Algebraic Thinking Level Determination Test" developed by the researchers was used to determine the algebraic thinking levels of the students. This test is for middle school students and aims to measure the first three levels of algebraic thinking. The KR-20 reliability coefficient of the 27-question test, which was obtained as a result of validity and reliability studies, was determined as 0.86. The average difficulty index of the test was 0.60 and the average discrimination index was 0.54. The "Geometric Thinking Levels Scale" developed by Alyesil (2005) was used to determine the geometric thinking levels of the students. The scale was prepared using the Van Hiele Geometry Test and consisted of 20 questions. The alpha-confidence coefficient was 0.81. It was accepted that students correctly answered four of the five questions at each level, indicating that level of thinking. These scales were applied to 2808 secondary school students in Izmit District of Kocaeli Province. 1071 students were 6th grade students, 996 students were 7th grade students and 771 students were 8th grade students. In the study, 6 students whose geometric thinking level was determined as the third level were selected. The grades in the Year-End Report of the previous year were taken into account in determining the grade point averages of the mathematics courses. Information about these students is shown in Table 1.

Table 1. Information about the participants of the study

Student's Name	Grade Level	Algebraic thinking level	Grade Average
Rana	6	1	86
Sarp	6	3	100
Metin	7	1	67
Ilgın	7	3	100
Tan	8	1	55
Asaf	8	3	100

Note. Pseudonyms were used in student names.

Data Collection and Application

The processes of forming the Pythagorean Theorem were discussed in determining the mathematical thinking skills of the students. In this sense, semi-structured interview questions were prepared. Interviews were held with each student in two separate sessions. In the first session, the theorem was presented to the students verbally. The aim here was for students to show the proof process based on the verbal situation. In the second session, a real-life situation was presented to the students, in which they were expected to form the theorem, and they were expected to show the dimensions of the three worlds of mathematics in the process. Students were asked questions about each thinking dimension. The real life situation given is as follows:

"In Efe's project assignment, his teacher asked him to design a house model. Efe wants the house to be designed in a very different model and to attract attention. Efe thinks for days and decides to design a house with 4 rooms. The features of the house are as follows:

- Three rooms will be square
- One wall of each of the square-shaped rooms will be perpendicular to each other
- These three rooms will overlap each other two by two from one corner
- The walls of the fourth room should be in common with one wall of each of these three rooms and this room should be located between them."

In the evaluation of the interviews, classifications were made by the researchers about the levels of the three worlds of mathematics. Expert opinion was taken for these classifications and it was decided that they were suitable for the theoretical framework. The thinking processes determined according to the three worlds of mathematics are as in Table 2.

Table 2. General framework of mathematical thinking processes in terms of the theoretical framework of the three worlds of mathematics

Dimensions of the three worlds of mathematics	Abilities
The Embodied World	Focus on the properties of the data in the expression Describing the concept, expressions or objects Demonstrating expressions by testing them with numbers
The Proceptual World	Reaching algebraic expressions, equations and inequalities as a result of the generalization process of mathematics
The Formal World	Expressing the proof process

While determining the general framework for the thinking processes about the three world dimensions of mathematics, the literature (Tall, 2007) was adhered to. If students showed at least one process in each dimension, their thinking processes were evaluated in that dimension.

In this study, which was carried out by obtaining the necessary permissions, the audio recordings of the interviews were transferred to the computer by the researchers. During the document review, the level of the three worlds of mathematics that the student showed in each question in the thinking process was marked and thus the dimension he/she reached was determined. The diversification method (Creswell, 2013) was used in the process of ensuring the validity and reliability of the semi-structured interview process. Documents and audio recordings of the interviews were examined and evaluated together. The solution papers of the students became an element that increased the validity in the interview process. In the evaluations of the researchers regarding the questions, it was determined that the Miles & Huberman (1994) agreement percentages were over 70%. This situation has been interpreted as a high consensus among researchers.

Results

In the semi-structured interviews held in this section, the mathematical thinking processes of the answers given by the students were evaluated. Firstly, the Pythagorean Theorem was presented to the students verbally. The evaluation of the answers given by the students participating in the study is presented in Table 3.

Table 3. Mathematical thinking dimensions of students for verbal expression of the Pythagorean Theorem

Dimensions of the three worlds of mathematics	Abilities	Rana	Sarp	Metin	Ilgın	Tan	Asaf
The Embodied World	Focus on the properties of the data in the expression	X	X	X			X
	Describing the concept, expressions or objects		X			X	X
	Demonstrating expressions by testing them with numbers	X	X		X	X	X
The Proceptual World	Reaching algebraic expressions, equations and inequalities a result of the generalization process of mathematics	X		X	X	X	X
The Formal World	Expressing the proof process				X		

In this part of the study, Rana drew a right triangle and showed its right angle and right sides. She tried to explain the expression by giving her own number values to the perpendicular side lengths. However, she had difficulties because the number value she obtained for the third side length was not a perfect square number. Because she could not explain which number is the square of this number. This is a normal situation since there are no acquisitions of square root expressions in the 6th grade curriculum. Despite all this, Rana was able to create a symbolic expression suitable for verbal expression. Therefore, her thinking process was evaluated in the proceptual world dimension. The interview process is as follows.

Rana: When we draw a right triangle, these sides become perpendicular. The steep sides are here and here. Now, let's get 7 here, and this is 4. The thing of 7 to the square of 7, 7 times 7 is 49. 4 to the power square also equals 4 times 4, is 16. When we add 49 and 16, it becomes 65. That's 4 squared by 7.

Researcher: Can you show it algebraically?

Rana: We can say that a squared, a squared plus b squared is equal to c.

Researcher: Is it equal to c?

Rana: It should be equal to its square. c squared.

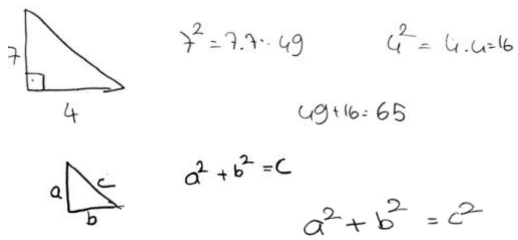


Figure 1. Symbolic representation of Rana for the verbally given Pythagorean Theorem

Sarp's level of thinking was limited to the embodied world dimension. Sarp was able to say that the concept of exponent was explained with the concept of square in the expression. He drew a right triangle and gave numerical values to the side lengths. While showing the expression in the question, he added the squares of the three side lengths and thought about how he should interpret the result he obtained. However, he could not explain. When he was asked to express the expression symbolically, he equated the sum of the squares of all the side lengths of a right triangle to the square of numbers. As a result, he made a mistake when he wanted to create a symbolic expression from the verbally given expression.

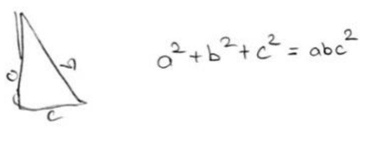


Figure 2. Symbolic representation of Sarp for the verbally given Pythagorean Theorem

Metin, illustrated by drawing the right triangle and right sides that explained to him in the verbal expression of the Pythagorean Theorem. He gave letters to the side lengths of the triangle. He was able to show the verbal expression symbolically. However, he did not give any explanation in terms of the accuracy of the statement. The thinking process was evaluated in the proceptual world dimension.

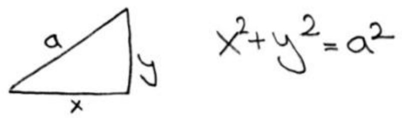


Figure 3. Symbolic representation of Metin for the verbally given Pythagorean Theorem

Ilgın, wanted to explain the expression by trying it with numbers first. Then she thought it would be more accurate to draw a right triangle and measure its sides. With the guidance of the researcher who conducted the interview, she drew a right triangle with vertical side lengths of 3 cm and 4 cm. She measured the third side of the triangle to be 5 cm. It demonstrated the numerical accuracy of the expression. She drew a right triangle again and gave letters to the side lengths. She was able to write a symbolic representation suitable for the expression. Thus, she developed a thinking process towards the formal world. Ilgın explained the verbal expression of the Pythagorean Theorem with the direction of the researcher. The interview process is as follows.

Ilgın: Can I draw a right triangle and show it? (She draws). This is 90 degrees. The steep sides are here and here. can I measure?

Researcher: Yes. But shall we do this? Let one of the perpendicular side lengths be 4 cm and the other 3 cm.

Ilgın: Okay, now let's draw it like this. This is 4 cm. This is 3 cm. If I measure here too, it's 5 cm. Now 3 times 3 I mean 3 squared is 9. 4 squared is 16. 16 plus 9 equals 25. And 5 squared makes 25. 25 equals 25 then this statement is true.

Researcher: Well, can you express it in algebraic notation?

Ilgın: The sum of a squared and b squared is equal to c squared.

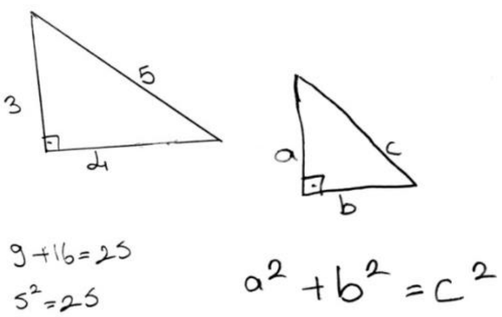


Figure 4. Symbolic representation of Ilgın for the verbally given Pythagorean Theorem

In this question about the Pythagorean Theorem, Ilgın wanted to develop a proof process that could explain the expression by drawing a right triangle and measuring the side lengths. The reason why the researcher directed Ilgın, who wanted to explain the accuracy of the expression, is because there is a possibility of reaching an expression with square roots. The subject of square root expressions is included in the 8th grade for the first time in the curriculum. In this sense, the researcher felt the need to guide the student.

Tan drew a right triangle and gave numerical values to the side lengths. He remembered that the expression told the Pythagorean Theorem. He continued to explain the statement instead of demonstrating its veracity. He was also able to write the appropriate relation for the expression. Therefore, the thinking process was evaluated in the proceptual world dimension.

Asaf stated that this statement was wrong, saying that the sum of the squares of the lengths of the right sides of a right triangle should be equal to the square of the length of the hypotenuse. He later realized that the length of the third side would be the hypotenuse. First, he wrote the appropriate correlation for the expression, then tried to explain it with a 3-4-5 triangle. However, he could not explain why the statement was true, and the thinking process was evaluated in the proceptual world dimension.

In the other part of the study, the real-life situation of discovering the Pythagorean Theorem was presented to the students. The mathematical thinking skills demonstrated by the students are presented in Table 4.

Table 4. Mathematical thinking dimensions of students to discover the Pythagorean Theorem in a real-life situation

Dimensions of the three worlds of mathematics	Abilities	Rana	Sarp	Metin	Ilgın	Tan	Asaf
The Embodied World	Focus on the properties of the data in the expression	X	X	X	X		X
	Describing the concept, expressions or objects	X	X	X	X	X	X
	Demonstrating expressions by testing them with numbers				X	X	X
The Proceptual World	Reaching algebraic expressions, equations and inequalities as a result of the generalization process of mathematics				X	X	X
The Formal World	Expressing the proof process				X	X	X

Rana first focused on the desired data in a real-life situation. Trying to draw a shape suitable for the data, she said that the part in between could be a triangle. However, she was unable to accurately draw the appropriate shape. Even though the part in between was a triangle as she drew, she could not show the other shapes as squares. Therefore, she could not develop a thinking process for the Pythagorean Theorem. The thinking process was evaluated in the embodied world dimension.

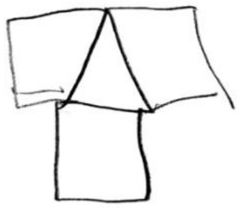


Figure 5. The process of creating the Pythagorean Theorem in Rana's real life situation

Sarp had to read the question several times to understand it. When he evaluated the data, he thought that the fourth room in between could be a right triangle. However, he gave up on this idea because he could not draw the right shape. Sarp, who thought that the room in between could be square, finally decided that this house could not be designed. The thinking process was evaluated in the embodied world dimension.

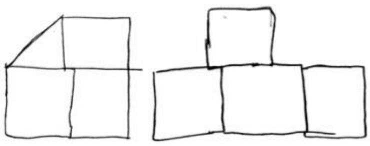


Figure 6. The process of creating the Pythagorean Theorem in Sarp's real life situation

Metin has read the statement many times, focusing on what is given. Then he wanted to draw the figure by trying to explain what was given. He tried to provide all the necessary conditions for the house by drawing more than one shape. He thought that the fourth room might be square, and he could not think about creating the Pythagorean Theorem. The thinking process has been limited to the embodied world dimension.

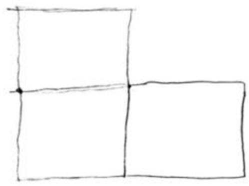


Figure 7. The process of creating the Pythagorean Theorem in Metin's real life situation

When Ilgın read the expression, she interpreted that the squares are perpendicular to each other as they must be parallel. Then she realized the mistake she made and developed a thinking to meet all the conditions. Ilgın was able to draw the correct shape. She stated that the fourth room in between would be a right triangle. Then, when asked to think of two perpendicular squares with a side of 3 cm and a side of 4 cm, she drew two squares of these lengths using a ruler.

She measured the side length of the third square as 5 cm. When she asked to find the area of the figure, she first calculated the areas of the squares. She explained the relationship between the areas of three squares as the sum of the areas of two squares equals the area of the third square. She was able to discover that the sum of the squares of the lengths of the two perpendicular sides of a triangle is equal to the square of the length of the third side. When she was asked what the third side length would be for a right triangle with side lengths of 6 cm and 8 cm, she said that the number 100 was obtained from the sum of its squares. She explained that the number 100 would be the square of this length. She was able to give the correct answer that it would be 10 cm. When she was asked to generalize this situation, she was able to express the Pythagorean Theorem symbolically. Thus, she developed a thinking process towards the formal world dimension.

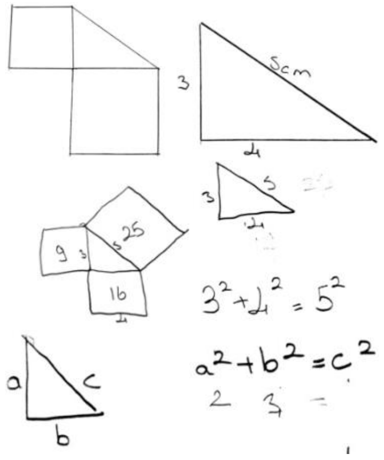


Figure 8. The process of creating the Pythagorean Theorem in Ilgın's real life situation

When Tan read the statement, he thought that the fourth room would be square. However; considering that the three rooms would overlap each other at the corners, he stated that the room in between could be an equilateral triangle. Then, when he evaluated that the two rooms should be perpendicular to each other, he said that the fourth room should be a right triangle. He was able to draw the correct shape. He stated that when one of the square rooms perpendicular to each other has a side length of 3 cm and the other a side length of 4 cm, he must use the Pythagorean Theorem to find the side length of the third square. He said that the side length of the third square would be 5 cm. When he asked why he took the squares, he replied that the sum of the areas of the given squares would equal the area of the third square. Tan, who explained the reason for a knowledge he had learned before and created the Pythagorean Theorem, carried out the formal world dimensional thinking process.

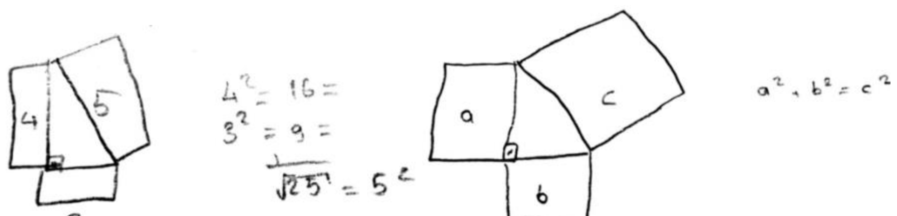


Figure 9. The process of creating the Pythagorean Theorem in Tan's real life situation

Asaf first explained what was requested. Then he drew the figure correctly and stated that the figure in between should be a triangle. When one of the squares perpendicular to each other has a side length of 3 cm and the other square has a side length of 4 cm, he measured the side length of the third square by drawing it with a ruler. He found the side length of the third square as 5 cm and said that this triangle is a right triangle since it is a special triangle of 3-4-5. Then, he developed a thinking process to explain the Pythagorean Theorem by making a connection between the side lengths of the triangle and the areas of the squares. The thinking process of Asaf, who formed the Pythagorean Theorem correctly, was evaluated in the formal world dimension.

The interview process is as follows:

Asaf: He will now design a 4 bedroom house. The three rooms of the house will be square and overlap one at a time. The fourth room will be in between. If I draw, the part in between would be a triangle. There are 4 rooms, three of them must be square and one of them must be triangles. I think it's a right triangle.

Researcher: What can you say about the side length of the third square if one of the perpendicular squares has a side of 3 cm and the side of the other is 4 cm?

Asaf: (Drawing and measuring). It should be 5 cm. Hmm, it's a 3-4-5 triangle.

Researcher: Is there a relationship between the areas of the squares?

Asaf: The side of this is 3 times 3, equals to 9. The area of this is 4 times 4, equals to 16. The area of this is 5 times 5, equals to 25. Hmm, the sum of the areas of the squares that are perpendicular is equal to the area of it. Then the sum of the squares of the right sides of the right triangle must be equal to the square of the other side. This is Pythagoras.

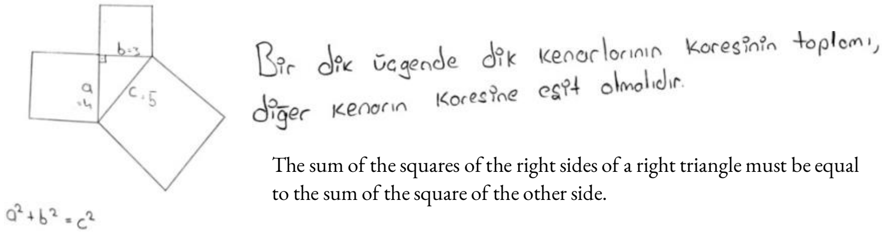


Figure 10. The process of creating the Pythagorean Theorem in Asaf's real life situation

Conclusion and Discussion

Students have difficulties in transitioning from concrete thinking to abstract thinking (Arslan & Yıldız, 2010; Keskin, Akbaba Dağ & Altun, 2013; Yeşildere & Türnüklü, 2007). One of the biggest challenges in mathematics education is the process of making sense of abstract concepts. In this process, we first use our concrete perceptions. Then, we evaluate abstract concepts within our existing mental schemes. The Pythagorean Theorem is a geometric construct involving abstract and symbolic thinking. In this study, the processes of students to form the Pythagorean Theorem were examined. In this process, mathematical thinking skills were evaluated. Mathematical thinking skills of 6th, 7th and 8th grade students with the same geometric thinking level were compared. When the relevant literature is examined (Açıl, 2015; Akarsu, 2022; Bağdat & Saban, 2014; Köse, 2018; Mudrikah, 2016; Türnüklü & Özcan; 2014), it is seen that the mathematical thinking processes of individuals are generally examined in terms of different theoretical frameworks such as APOS, SOLO Taxonomy and RBC Theory. In this study, the three worlds of mathematics were used as the theoretical framework.

In the study, geometric thinking levels were taken as a criterion in the selection of students. The geometric thinking levels of the six participants with whom the study was conducted together were determined as the third level. In addition, the algebraic thinking levels of the students were discussed. According to the theoretical framework of the three worlds of mathematics, mathematical thinking takes place in three stages (Tall, 2007). These stages follow a path from concrete to abstract. The reason why students' geometric thinking levels were chosen as third level in this study is to evaluate the progress of their thinking processes towards the formal world dimension. At secondary school level, students are not expected to be able to prove the equation fully. However, it was thought that they could show the proof process within their thinking process. Therefore, the results of the study also support this idea. In the thinking processes developed based on the verbal expression of the Pythagorean Theorem, the thinking levels of 6th and 8th grade students could not reach the formal world dimension. The 6th grade student, whose algebraic thinking level is at the first level, was able to create symbolic expression based on verbal expression. Since the 6th grade level is the grade level in which the subject of algebraic expressions is introduced, it is one of the important results of the research that the student can create symbolic expressions in accordance with the theorem. The 6th grade student, whose algebraic thinking level is at the third level, could not correctly show the symbolic expression for the verbal expression of the theorem. 7th and 8th grade students were able to create symbolic expressions suitable for verbal expression. In addition, the 7th grade student, whose algebraic and geometric thinking level was at the third level, was able to realize formal world dimensional thinking process.

In the process of creating the Pythagorean Theorem based on the real life situation, the thinking levels of the 6th grade students were limited to the embodied world dimension. The 7th grade and 8th grade students, whose algebraic thinking level was at the third level, were able to show all the thinking processes of the three worlds of mathematics. The result of the study shows that a 7th grade student with a third level of algebraic and geometric thinking was able to develop a thinking process towards the formal world dimension on a subject that he had not learned before. In the study, it was concluded that as the grade level increased, the thinking skills of the students also increased. In addition, students who could not develop a proof process in the oral expression of the Pythagorean Theorem were able to construct the theorem in real life situations. This showed that students were able to use their mathematical thinking skills more accurately in real-life situations.

Another result of the research is that 8th grade students have more problems in interpreting verbal expression despite being taught about the Pythagorean Theorem. They were able to construct the theorem in a real-life situation. Therefore, although the students stated that the verbal expression was the Pythagorean Theorem, their inability to explain the theorem led to the thought that they could not achieve permanent learning. The students memorized the application of the theorem in the context of the operational process. In the real-life situation, however, since no information about the Pythagorean Theorem was presented in the real-life situation, the process of discovering the theorem was able to be realized. In this sense, learning environments should be provided in schools where students can develop a thinking process towards the formal world dimension.

In this study, it was observed that the students were able to draw appropriate geometric shapes regarding the verbal instructions given in real life situations. This situation was interpreted as the fact that their geometric thinking levels were at the third level. As the grade level increased, the students' ability to create appropriate symbolic expressions increased.

In this study, it was observed that the difficulties experienced by the students in geometry affected their ability to develop the proof process. However, the study showed that middle school students were able to perform the proof process in geometry. In the study of Miyazaki et al. (2017), secondary school students were able to express the proof process in geometry. In particular, they stated that students with third and fourth level geometric thinking were more successful.

As a result of the research, it is seen that it is important to design activities and course environments that will reveal students' thinking skills for mathematical thinking processes. In the verbal expression, while the students were trying to understand the concepts, they carried out a thinking process to create the concepts in a real life situation. Verbal expression helped them create symbolic expressions about concepts. They had difficulty in carrying out the proof process. Therefore, it is thought that to enable students to discover the concepts in the activities instead of presenting them directly in the teaching process is important. According to Fidan and Türnüklü (2010), instead of giving the geometric concepts to the students directly, the students should be encouraged to find and create these concepts and they should be given education according to their level. Measurement and evaluation processes can also be assessed in this context.

Recommendations

With this research, the applicability of the theoretical framework of the three worlds of mathematics on geometry was discussed. In future studies, the applicability of the theoretical framework can be evaluated within other fields of mathematics. In addition, since thinking will progress in the process according to the three worlds of mathematics, studies that examine the thinking process in terms of grade levels can also be conducted.

Limitations of Study

The limitation of this study is that the fifth grade students, who are among the secondary school students, were not selected among the participants of the study. Because the achievements of algebra in the mathematics curriculum start from the sixth grade level. Since there is no algebraic achievement at the fifth grade level, fifth grade students were not selected as participants.

Acknowledgments

We would like to thank the students who participated in the study and answered the study questions sincerely. All authors contributed equally to the study. The authors declare that there is no conflict of interest. Ethical rules were followed in all processes of the study.

Biodata of the Authors

Dr. **Esra Akarsu Yakar** completed her master's and doctorate in Dokuz Eylül University Institute of Educational Sciences, department of mathematics education. Her research interests are in mathematical thinking, the three worlds of mathematics, procept theory, mathematical language, algebraic and geometric thinking. Affiliation: Ministry of National Education. E-Mail: es.akarsu@gmail.com, ORCID: 0000-0002-4090-6419

Prof.Dr. **Suha Yilmaz** continues his academic life in Dokuz Eylül University, Buca Faculty of Education, Department of Mathematics and Science Education. His research interests are differential geometry, mathematical thinking, spatial thinking, mathematical modeling and technology in mathematics education. Affiliation: Dokuz Eylul University, Buca Faculty of Education, Department of Mathematics and Science Education. ORCID: 0000-0002-8330-9403

References

Açan, H. (2015). *Examining 8th graders'knowledge construction processes in transformation geometry* [Unpublished master's thesis]. Dokuz Eylul University.

Açıl, E. (2015). *Investigation of middle school 7rd graders abstraction processes of the concept of equation: APOS theory* [Unpublished doctoral thesis]. Ataturk University.

Akarsu, M. (2022). Understanding of geometric reflection: John's learning path for geometric reflection. *Journal of Theoretical Educational Science*, 15 (1) , 64-89. DOI: 10.30831/akukeg.952022

Alkan, H. & Güzel, E. B. (2005). Development of mathematical thinking in the student teachers. *Gazi University Journal of Gazi Education Faculty*, 25 (3) , 221-236. Retrieved from https://dergipark.org.tr/tr/pub/gefad/issue/6755/90835

Alyeşil, D. (2005). *The effect of geometry learning with the method of conception charts supported problem solving to the 7th class students' geometry thinking level* [Unpublished master's thesis]. Dokuz Eylul University.

Arslan, S. & Yıldız, C. (2010). Reflections from the Experiences of 11th Graders during the Stages of Mathematical Thinking. *Education and Science*, 35(156), 17-31.

Bağdat, O. & Saban, P. (2014). Investigation of the 8th grade students' algebraic thinking skills with solo taxonomy. *International Journal of Social Science*, 26 (2), 473-496.

Bal, A.P. & Dinç Artut,P. (2020). Developing the Mathematical Thinking Scale: Validity and Reliability. *Journal of Çukurova Education Faculty*, 49 (1), 278-315.

Bobango, J. C. (1988). Van Hiele levels of geometric thought and student achievement in standard content and proof writing: The effect of phase-based instruction. *Dissertation Abstract Index*, 48 (10).

Breen, J. J. (2000). Achievement of Van Hiele level two in geometry thinking by eight grade students through the use of geometry computer-based guided instruction. *Dissertation Abstract Index*, 60 (07).

Burton, L. (1984). Mathematical thinking: The struggle for meaning. *Journal for Research in Mathematics Education*, 15 (1), 35-49.

Chan, C.C, Tsui, M.S, Chan, M.Y.C. & Hong, J.H. (2002). Applying the structure of the observed learning outcomes (SOLO) taxonomy on student's learning outcomes: An empirical study. *Assessment and Evaluation in Higher Education*, 27 (6).

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches* (4nd ed.). Thousand Oaks, Sage.

Doğan, M. & Güner, P. (2012, June). *Examination of pre-service primary school mathematics teachers' skills of understanding and using mathematics language*. Paper presented at the X. National Science and Mathematics Education Congress, Niğde University, Niğde.

Dreyfus, T. (1991). Advanced mathematical thinking processes. In D. O. Tall (Ed.). *Advanced Mathematical Thinking*. USA: Kluwer Academic Publishers. 25-41.

Fidan, Y. (2009). *The geometric thinking levels of primary grade 5 students and the effect of geometry teaching with discovery learning on geometric thinking levels of students* [Unpublished doctoral thesis]. Dokuz Eylul University.

Fidan, Y. & Türnüklü, E. (2010). Examination of 5th grade students' levels of geometric thinking in terms of some variables. *Pamukkale University Journal of Education*, 27 (27), 185-197.

Freudenthal, H. (1973). *Mathematics as an educational task*. The Netherlands:Riedel Publishing Company.

Fuys, D., (1985). Van Hiele levels of thinking in geometry. *Education and Urban Society*, 17(4), 447-462.

Groth, R. E. & Bergner, J.A. (2006). Preservice elementary teachers' conceptual and procedural knowledge of mean, median, and mode. *Mathematical Thinking and Learning*, 8 (1), 37-63.

Gündoğdu Alaylı, F. (2012). *The investigation of thinking process of primary 6th ,7th and 8th grade students in the studies of composing and decomposing shapes in geometry and determination of their levels in this process* [Unpublished doctoral thesis]. Dokuz Eylul University.

Hannah, J., Stewart, S. & Thomas, M. O. J. (2016). Developing conceptual understanding and definitional clarity in linear algebra through the three worlds of mathematical thinking. *Teaching Mathematics and Its Applications*, 35, 216-235.

Henderson, P. B., Fritz, S. J., Hamer, J., Hitcher, L., Marion, B., Riedesel, C. & Scharf, C. (2002). *Materials development in support of mathematical thinking*. The 7th Annual Conference on Innovation and Technology in Computer Science Education, Working Group Report, ACM SIGCSE Bulletin, 35 (2), 185–190.

Jukić, L. & Brückler, F.M. (2014). What do croatian pre-service teachers remember from their calculus course?. *Issues in the undergraduate mathematics preparation of school teachers*, 1,1-15.

Karakarçayıldız, R. Ü. (2016). *Geometrical thinking levels and polygons classification skills of 7 th grade students and relationship between them* [Unpublished master's thesis]. Eskisehir Osmangazi University.

Kashefi, H., Ismail, Z. & Yusof, Y.M. (2010). Obstacles in the lerning of two-variable functions through mathematical thinking approach. *Pocedia Social and Behavioral Sciences*, 173-180.

Keskin, M. , Dag, S. A. & Altun, M. (2013). Comparison of 8th and 11th grade students behaviours at mathematical thinking, *Journal of Educational Science* , 1 (1) , 33-50. Retrieved from https://dergipark.org.tr/tr/pub/jedus/issue/16124/168704

Kidron, I. (2008). Abstraction and consolidation of the limit procept by means of instrumented schemes: The complementary role of three different frameworks. *Educational studies in mathematics*, 69, 197-216.

Köse, O. (2018). *Determination of SOLO taxonomy levels of mathematics teacher candidates with high level saptial ability accordingto thinking structures* [Unpublished master's thesis]. Selçuk University.

Liu, P. H. (2003). Do teachers need to incorporate the history of mathematics in their teaching?. T*he Mathematics Teacher*, 96 (6), 416-421.

Liu, P. H. & Niess, M. L. (2006). An exploratory study of college students' views of mathematical thinking in a historical approach calculus course. *Mathematical Thinking and Learning*, 8 (4), 373-406.

Lucas, U. & Mladenovic, R. (2008). The identification of variation in students' understandings of disciplinary concepts: The application of the SOLO taxonomy within introductory accounting. *Higher Education*, 58 (2), 257-283. doi:10.1007/s10734-009-9218-9

Martínez-Planella, R. & Triguerosb, M. (2019). Using cycles of research in APOS: The case of functions of two variables. *The Journal of Mathematical Behavior*, 53, 1-22.

Mason, J., Burton, L. & Stacey, K. (2010). *Thinking mathematically*. Pearson Education Limited.

Miles, M, B. & Huberman, A. M. (1994). *Qualitative data analysis: An expanded Sourcebook*. (2nd ed). Thousand Oaks, Sage.

Mistretta, R. M. (2000). Enhancing geometric reasoning. *Adolescence*, 35 (138), 365-379.

Miyazaki, M., Fujita, T. & Jones, K. (2017). Students' understanding of the structure of deductive proof. *Educational Studies in Mathematics*, 94, 223-239. doi: 10.1007/s10649-016-9720-9

MoNE (2018). *Mathematics Course Curriculum* (1st-8th Grades). Ankara: MEB.

Mubark, M. (2005). *Mathematical thinking and mathematical achievement of students in the year of 11 scientific stream in Jordan* [Unpublished doctoral thesis]. New Castle University.

Mudrikah, A. (2016). Problem-based learning associated by action-process-object-schema (APOS) theory to enhance students' high order mathematical thinking ability. *International Journal of Research in Education and Science (IJRES)*, 2 (1), 125- 135.

National Council For School Mathematics (2000). *Principles and standarts for school mathematics*. Reston, Va: Author.

Olkun, S., Toluk, Z. & Durmuş, S. (2002, September). *Geometric thinking levels of primary school and mathematics teaching students*. Paper presented at the 5th National Science and Mathematics Education Congress, ODTÜ, Ankara.

Özcan, B.N. (2012). *The investigation of knowledge construction process of primary school students while developing geometric thinking levels* [Unpublished doctoral thesis]. Dokuz Eylul University.

Polya, G. (1945). *How to solve it: A new aspect of mathematical method*. Princeton University Press.

Ramdhani, S. & Suryadi, D. (2018). The analogical reasoning analysis of Pesantren students in geometry. *Journal of Physics Conference Series*,1132 (1).

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition and sensemaking in mathematics. In

Grouws, D. (Ed), *Handbook for Research on Mathematics Teaching and Learning*, (334-370), MacMillan.

Stacey, K. (2006). *What is mathematical thinking and why is it important? Progress report, Collaborative Studies on Innovations for Teaching and Learning Mathematics in Different Cultures* (II)-Lesson Study focusing on Mathematical Thinking, University of Tsukuba.

Tall, D. O. (1995). *Cognitive growth in elementary and advanced mathematical thinking*, in D. Carraher and L. Miera (eds.), Proceedings of XIX International Conference for the Psychology of Mathematics Education, 1, 61–75, Recife, Brazil.

Tall, D. (2002). *Advanced mathematical thinking*. Kluwer Academic Publishers

Tall, D. (2006). A Theory of mathematical growth through embodiment, symbolism and proof. *Annales De Didactique Et De Sciences Cognitives*, 11, 195-215.

Tall, D. (2007). Developing a theory of mathematical growth. *Zdm Mathematics Education*, 39, 145-154.

Tall, D., Lima, R. N. & Healy, L. (2014). Evolving a three-world framework for solving algebraic equations in the light of what a student has met before. *The Journal of Mathematical Behavior*, 34, 1-13.

Tsamir, P. & Dreyfus, T. (2002). Comparing infinite sets – A process of abstraction: The case of Ben. *Journal of Mathematical Behaviour*, 21, 1-23.

Tuluk, G. & Dağdelen, I. (2020). The Investigation of geometric thinking levels of fifth year students who started to primary school at different ages. *International Journal of Scientific and Technological Research*, 6 (9).

Türnüklü, E. & Özcan, B. (2014). The relationshıp between students' construction of geometric knowledge process based on rbc theory and van hiele geometric thinking levels: Case study. *Mustafa Kemal University Journal of Graduate School of Social Sciences*, 11 (27), 295-316.

Usiskin, Z. (1982). *Van Hiele levels and achievement in secondary school geometry, Final Report*, Cognitive Development And Achievement in Secondary School Geometry Project. Chicago: University Of Chicago.

Van De Walle, J. (2004). *Elemantary and middle school mathematics: Teaching developmentally* (5th edition). Boston: Allyn & Bacon.

Vandebrouck, F. (2011). *Students conceptions of functions at the transition between secondary school and university*. Proceedings of the Conference CERME 7, University of Rzeszow, Poland.

Van Hiele, P. M. (1986). *Structure and insight: A theory of mathematics education*. Academic Pr.

Yeşildere, S. (2006). *The Investigation of mathematical thinking and knowledge construction processes of primary 6, 7 and 8th grade students who have different mathematical power* [Unpublished doctoral thesis]. Dokuz Eylul University.

Yeşildere, S & Türnüklü, E. (2007). Examination of students' mathematical thinking and reasoning processes. *Ankara University Journal of Faculty of Educational Sciences (JFES)* , 40 (1) , 181-213 . DOI: 10.1501/Egifak_0000000156

JMETP

Journal for the Mathematics Education and Teaching Practices, 3(2), 101-109, Dec 2022
e-ISSN: 2717-8587
dergipark.org.tr/jmetp

Young Wise Publishing
youngwisepub.com
gencbilgeyayincilik.com © 2022

Research Article

Instructional multimedia with local context oriented to numeracy skills: practicality and effectiveness

Nilza Humaira Salsabila[1], Baidowi[2], Syahrul Azmi[3], Ulfa Lu'luilmaknun[4]

Universitas Mataram, Faculty of Teacher Training Education, Mathematics Education Study Program, Indonesia

Article Info

Received: 7 November 2022
Accepted: 25 December 2022
Available online: 30 Dec 2022

Keywords:
Instructional multimedia
Local Context
Numeracy Skills

Abstract

The aim of this research is to develop instructional multimedia with local context of Lombok Island for junior high school students. The development of instructional multimedia is oriented towards numeracy skills on the probability topic. This research is development research based on the design research model by Plomp which consists of 3 phases, namely Preliminary Research, Development or Prototyping, and Assessment. The subjects in this research were grade IX junior high school students consisting of 24 students. The data were collected using practicality questionnaire to determine the practicality of multimedia and numeracy skills test to determine the effectiveness of multimedia. The results showed that instructional multimedia met the practical and effective criteria. The results of the teacher's assessment showed a total score is 32 in practical classification. Then 83% of students gave an assessment of being in the very practical classification and 17% were in the practical classification. The results of the effectiveness of the numeracy skills test showed that 79% of students achieved the Minimum Completeness Criteria score. Therefore, instructional multimedia is practical and effective for mathematics learning oriented to students' mathematical numeracy skills.

To cite this article

Salsabila N. H., Baidowi, Azmi S., & Lu'luilmaknun U. (2022). Instructional multimedia with local context oriented to numeracy skills: practicality and effectiveness. *Journal for the Mathematics Education and Teaching Practices, 3*(2), 101-109.

Introduction

Numeracy skills is an individual's ability to implement mathematical concepts and skills in solving daily life problems (The Ministry of Education and Culture, 2017). Gerakan Literasi Nasional (2017) also revealed the same point that numeracy skills is related to someone's skills to apply various data and mathematical symbols, as well as their various skills in making solutions to solve real problems. Elements of numeracy include knowledge, understanding, and numeracy skills that a person uses to communicate the language of mathematics and to recognize the relationship between knowledge of mathematics (Yunarti & Amanda, 2022).

Numeracy skills is needed as the basis for high-order thinking skills and are needed to solve problems (Inovasi, 2019). In addition, numeracy skills can help a person to be sensitive to existing data and patterns, as well as strengthen one's

[1] Corresponding Author: Lecturer in Mathematics Education Study Program, Faculty of Teacher Training Education, Universitas Mataram, Indonesia. E-mail: nilza_hs@unram.ac.id ORCID: 0000-0001-5244-5026

[2] Lecturer in Mathematics Education Study Program, Faculty of Teacher Training Education, Universitas Mataram, Indonesia. E-mail: baidowi.fkip@unram.ac.id ORCID: 0000-0001-5244-5026

[3] Lecturer in Mathematics Education Study Program, Faculty of Teacher Training Education, Universitas Mataram, Indonesia. E-mail: syahrulazmi.fkip@unram.ac.id ORCID: 0000-0001-5244-5026

[4] Lecturer in Mathematics Education Study Program, Faculty of Teacher Training Education, Universitas Mataram, Indonesia. E-mail: ulfa_l@unram.ac.id ORCID: 0000-0003-3504-1278

reasoning abilities which function in making decisions to solve problems (Yunarti & Amanda, 2022). This skill is needed by everyone to deal with various problems that occur in various aspects of life. It can be said that numeracy skills is one of the important basic skills to be mastered by students.

However, the students' numeracy skills in Indonesia have not obtained satisfactory score. This is based on the Program for International Student Assessment (PISA) results in Indonesia in 2015 and 2018. In 2015, Indonesia obtained an average score of 386 for mathematics out of an average score of 490 for each country (OECD, 2016). Then it decreased in 2018, the average math score reached 379 with an average score of 487 (OECD, 2019). Indonesia is in position 73 of 79 countries in math score. Therefore, it is important for educational practitioners to find solutions to this problem.

One of the solutions offered to improve numeracy skills is to develop interactive multimedia oriented to numeracy skills. Multimedia is a integration of integration of several elements in media like text (alphabetical or numeric), symbols, figures, sound, video, and animation usually using technology for the purpose to improving students' understanding (Guan, Song, & Li, 2018). Interactive multimedia involving images and animations can affect students' mathematical skills (Nusir, Alsmadi, Al-Kabi, & Sharadgah, 2012). Students can be directly involved in mathematics learning through the interactive element of multimedia (Benny, 2017).

In addition to interactive multimedia, learning that involves local contexts will make students easier to receive the material. Local context in mathematics learning can change students' thinking that mathematics is a fun subject that is linked to students' local culture (Indriani & Imanuel, 2018). Besides that, the local context in learning can influence changes in students' understanding of mathematical objects, the role and function of the learning context (Febrian, Astuti, & Antika, 2019). Students' numeracy skills can be used to solve daily problems so that learning is more meaningful (Jamil & Khusna, 2021).

Previous research has shown that interactive multimedia can help students learn mathematics. This will affect students' abilities in mathematics, especially numeracy skills. The implementation of instructional game, which is interactive multimedia, with local context can be used in mathematics learning (Safitri, Pujiastuti, & Sudiana, 2020). Furthermore, this media can improve students' cognitive aspects, such as conceptual understanding (Salsabila & Setyaningrum, 2020), and affective aspects, such as learning interest (Salsabila & Setyaningrum, 2018), in mathematics.

So, based on the previous description, it can be concluded that interactive multimedia with local contexts has the potential to help students' mathematics learning process. Thus, the development of interactive multimedia with a local context oriented to numeracy skills of junior high school students can be one solution to improve students' skills.

Problem of Research

The problem formulation in this research, based on the introduction above, is

- How is the practicality and effectiveness of interactive multimedia with a local context oriented towards the mathematical numeracy skills of junior high school students?

Method

Research Model

This research is development research based on the design research model by Plomp which consists of 3 phases, namely Preliminary Research, Development or Prototyping, and Assessment (Plomp, 2013). This research aims to develop products and assest the quality of these products. The product developed is in the form of interactive multimedia with the local context of Lombok Island for junior high school students. The development of instructional multimedia is oriented toward numeracy skills. Developed multimedia that presents probability topic. The assessment of the feasibility of the product or multimedia developed refers to the criteria of Nieveen, which meet the criteria of validity, practicality, and effectiveness (Nieveen, 1999). Product feasibility assessment is carried out in the Assessment phase. In this article, we will discuss the practicality and effectiveness of products that have previously met valid criteria.

Participants

The subjects in this research were grade IX students of junior high school 2022/2023 Academic Year. The students consist of 24 students, with 10 male students and 14 female students.

Data Collection Tools

The data collection techniques used in this research consisted of non-test and test techniques. In the non-test technique, the researcher used a practicality assessment questionnaire that was filled out by teachers and students. Then in the test technique, the instrument is used to test students' numeracy skills on the probability. These various instruments are used to determine the quality and feasibility of the developed learning multimedia. Data from practicality assessment questionnaires were used to determine the multimedia practicality and data from numeracy skills tests were used to determine multimedia effectiveness.

The practicality assessment questionnaire instrument by teachers and students each consists of 10 statements containing several statements related to the usefulness and ease of use of multimedia. The practicality assessment questionnaire uses a Likert 4 scale, which consists of strongly agree, agree, disagree, and strongly disagree. Meanwhile, the scores obtained through the practicality assessment questionnaire of teachers and students are classified based on the classification in the table below (Widoyoko, 2016).

Table 1. Practicality classification of instructional multimedia based on teacher and student assessment

Empirical Score Interval (X)	Classification
$X > 34$	Very Practical
$28 < X \leq 34$	Practical
$22 < X \leq 28$	Practical enough
$16 < X \leq 22$	Not Practical
$X \leq 16$	Very Impractical

Then the numeracy skills test instrument consists of 3 essay questions. The questions given are related to the probability material for students in junior high school. The following is an example of a question contained in a student's numeracy skills test.

"Mr. Aldi and his son, Sani, eat at the Lombok Restaurant which provides the menu below. If Sani is allowed to choose one food, drink and snack each, how many possible menus can Sani choose? Identify the menu list."

Food	Drink	Snack
Pelecing Sate Bulayak Urap	Es Sarang Burung Poteng Isi	Cerorot Bantal

Furthermore, there are two criteria for interactive multimedia to be practical, that is: (1) the results of the teacher's assessment score on the mathematics instructional multimedia are at the minimum criteria 'practical' and (2) at least 75% of the students' assessment scores of the mathematics instructional multimedia are at the minimum criteria 'practical'. Then for multimedia effectiveness, it has criteria, at least 75% of the overall students reach the score Minimum Completeness Criteria which is 75.

Results

The product developed in this research is instructional multimedia with local context oriented to numeracy skills. The local context used is the local context on the Lombok island, Nusa Tenggara Barat. The local context referred to in this research is the context used to build mathematical concepts through local situations. An example of a local context that is used as numeracy learning in this media is how students have the same probability to play traditional Lombok instruments in turn. Then students can also determine how many possible menus a person can order from a traditional

Lombok restaurant. The material delivered in multimedia uses local contexts, such as traditional tools, traditional foods, and others, which are close to the student's environment. The display of the multimedia is following below. The display of the multimedia is following below.

Figure 1. Interactive Multimedia Display

Furthermore, the data obtained from the Development or Prototyping phase are used by researchers to measure the practicality and effectiveness of interactive multimedia. Analysis of practicality and effectiveness is carried out in the Assessment phase. The following is an explanation of the aspects of practicality, and effectiveness in this research.

Instructional Multimedia Practicality

The practicality of instructional multimedia can be seen from the results of the practicality assessment of teachers and students. The assessment sheet for the practicality of multimedia of the teacher is filled out by mathematics teacher at IX grade junior high school. The teacher's assessment result showed a total score 32 in 'practical' classification. Based on the table below, it can be concluded that interactive multimedia meets the practical criteria.

Table 2. Instructional multimedia practicality based on teacher's assessment

No	Information	Result
1	Number of items	10
2	Maximum score	40
3	Minimum score	10
4	Total score	32
5	Classification	Practical

Furthermore, the students also gave an assessment of interactive multimedia after using it. The multimedia practicality based on students' assessment and the result practicality classification of instructional multimedia by students can be seen in the table below.

Table 3. Instructional multimedia practicality based on students' assessment

No	Information	Result
1	Number of items	10
2	Maximum score	40
3	Minimum score	10

4	Highest score	40
5	Lowest score	31
6	Average score	36.08

The following are the details of the multimedia practicality classification by students.

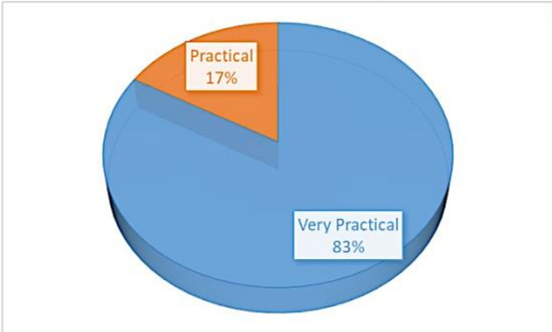


Figure 2. Multimedia practicality classification by students

Based on the data above, it can be seen that 83% of students' multimedia assessment gave 'very practical' classification, 17% gave 'practical' classification, and 0% of students gave 'practical enough', 'impractical' and 'very impractical' classification. It can be concluded that the learning multimedia meets the practical criteria.

Then the practicality data by students is also detailed by gender in the diagram below.

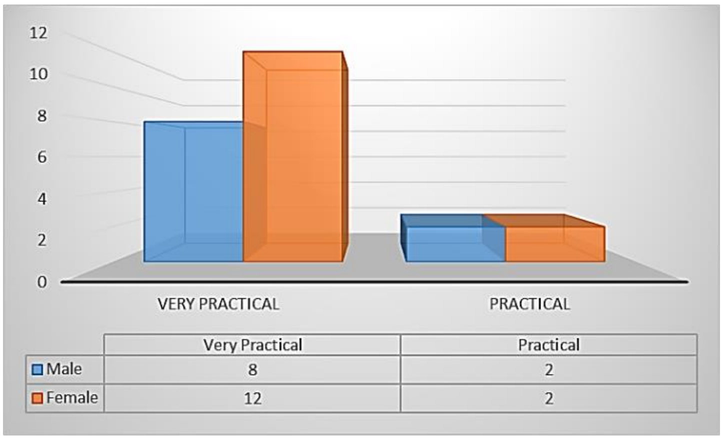


Figure 3. Multimedia practicality classification based on students' gender

It can be seen that only 2 students, each male student and female student, whose assessment is in the 'practical' classification. Most male and female students' assessments are in the 'very practical' classification. This indicates that multimedia is useful and easy to use for both male and female students.

Instructional Multimedia Effectiveness

The results of students' numeracy tests were used in research to determine the effectiveness of the developed instructional multimedia. The instructional multimedia effectiveness criteria in this research are at least 75% of the overall students achieve the Minimum Completeness Criteria score or MCC. The student's Minimum Completeness Criteria score in mathematics is 75. The following are the results of the student's numeracy skills test after using interactive multimedia.

Table 4. Student's numeracy skills test results

No	Information	Result
1	Number of students	33
2	Highest score	100
3	Lowest score	65
4	Average score	77.08

5	Number of students achieve MCC	19
6	Percentage	79%

Based on the table above, it can be seen that the average score of students' numeracy test is 77.08. In addition, the percentage of students who achieve the Minimum Completeness Criteria score is 79% or 19 students. Therefore, it can be concluded that multimedia is effective based on the results of students' numeracy skills tests.

Then we also detail the student's numeracy skills test result based on gender in the table below.

Table 5. Student's numeracy skills test results based on gender

No.	Information	Male	Female
1	Number of students	10	14
2	Highest score	85	100
3	Lowest score	65	65
4	Average score	77	77.14

Based on table above, it can be seen that the average scores of male and female students are not much different. The highest score for the results of the numeracy skills test was obtained by female students. Then the average value of the numeracy skills test for female students is higher than that of male students. This shows that the numeracy skills of female students are better than those of male students.

Conclusion and Discussion

Based on the result, interactive multimedia developed that meets practical and effective criteria. Interactive multimedia contains local contexts that are oriented towards numeracy skills on probability material. The results of the teacher's assessment showed a total score of 32 in the 'practical' classification. Then 83% of students gave an assessment in 'very practical' classification and 17% were in 'practical' classification. Then the effectiveness of the product based on the students' percentage who meet the Minimum Completeness Criteria score on the numeracy skills test reaching 79%. Thus, instructional multimedia is feasible to use for mathematics learning oriented to students' numeracy skills.

Several previous research have shown that multimedia can help students learn mathematics (Chiu & Mok, 2017; Ulusoy, 2020). The implement of interactive multimedia can also improve students' numeracy skills (Handayani, 2018; Rohendi, Sumarna, & Sutarno, 2017). Furthermore, instructional multimedia such as educational games, whose characteristics resemble interactive multimedia, can develop students' cognitive and affective abilities in mathematics learning (Salsabila et al., 2021; Salsabila & Setyaningrum, 2020, 2019, 2018). In addition, educational games can also facilitate students' numeracy skills (Nurfatanah, Yudha, Marini, & Sumantri, 2021; Rohendi, 2019).

This is because interactive multimedia displays images and information simultaneously in learning (Mayer, 2014), which can attract students' attention (Handayani, 2018). Interactive multimedia can stimulate students' mathematical understanding through attractive visual presentations (Ahmad, Yin, Fang, Yen, & How, 2010; De Vita, Verschaffel, & Elen, 2014). Then, fun learning through multimedia encourages students to be actively involved in mathematics learning (Miller, 2018). The teacher in this case as a facilitator in the classroom certainly has an important role in the implement media in the classroom (Jiang, Mok, & Yin, 2021; Legesse, Luneta, & Ejigu, 2020; Russo et al., 2020). The appliance of this multimedia will provide a mathematics learning experience by utilizing technology for teachers and students (Chen & Wu, 2020; Clark-Wilson & Hoyles, 2019).

Furthermore, the learning multimedia developed containing the local context of Lombok Island can help students learn mathematics (Irawan, Lestari, Rahayu, & Dwitiyanti, 2022; Kurnia, Azmi, Yuberta, Maris, & Apriliani, 2022), which in this case certainly has a role in the feasibility of multimedia. The local context provided by multimedia shows that it can develop students' numeracy skills (Jamil & Khusna, 2021; Kamsurya & Masnia, 2021). It is important in learning to develop media with local contexts to build students' numeracy skills (Damayanti, Roza, & Maimunah, 2022).

Students will find it easier to explore the material presented in multimedia if they use local contexts that are close to their daily lives. The local context in mathematics learning also makes students interested and enthusiastic (Aziz, Suprayitno, Prahmana, & Prasetyo, 2021; Priyani, 2022). In addition, numeracy questions designed according to the local context of students, such as tourism areas around students, can help students understand the information in the questions (Ariyanto & Kusumaningsih, 2022).

Recommendations

Instructional multimedia with local context oriented to numeracy skills needs to be further developed in other topics. In addition, instructional multimedia can also facilitate the development of other student skills, besides numeracy skills. Some elements in multimedia also need to be developed more sophisticated to be effective in learning.

Limitation of Study

Instructional multimedia with local context was developed only on junior high school probability topic. In addition, instructional multimedia focuses on students' numeracy skills. The subject of this research was also limited to grade IX students in the one of junior high schools in Indonesia.

Acknowledgments

This research took place with the support of the Institute for Research and Community Service, Universitas Mataram through the PNBP-2022 Grant.

References

Ahmad, A., Yin, T. S., Fang, L. Y., Yen, Y. H., & How, K. W. (2010). Incorporating multimedia as a tool into mathematics education: A case study on diploma students in multimedia university. *Procedia - Social and Behavioral Sciences*, *8*, 594–599. https://doi.org/10.1016/j.sbspro.2010.12.082

Ariyanto, S. L., & Kusumaningsih, W. (2022). *Minimum Competency Assessment Design to Improve Mathematical Literacy in Junior High Schools*. *2022*, 64–75. https://doi.org/10.18502/kss.v7i14.11954

Aziz, A., Suprayitno, I. J., Prahmana, R. C. I., & Prasetyo, P. (2021). Ethnomathematics for elementary school students in Kebumen Regency using corn plant media. *The 12th International Conference On Lesson Study*, 181–186.

Benny, A. (2017). *Media & Teknologi dalam Pembelajaran*. Jakarta: Kencana.

Chen, C. L., & Wu, C. C. (2020). Students' behavioral intention to use and achievements in ICT-Integrated mathematics remedial instruction: Case study of a calculus course. In *Computers and Education* (Vol. 145). Elsevier Ltd. https://doi.org/10.1016/j.compedu.2019.103740

Chiu, T. K. F., & Mok, I. A. C. (2017). Learner expertise and mathematics different order thinking skills in multimedia learning. *Computers and Education*, *107*, 147–164. https://doi.org/10.1016/j.compedu.2017.01.008

Clark-Wilson, A., & Hoyles, C. (2019). From curriculum design to enactment in technology enhanced mathematics instruction—Mind the gap! *International Journal of Educational Research*, *94*(March), 66–76. https://doi.org/10.1016/j.ijer.2018.11.015

Damayanti, N., Roza, Y., & Maimunah, M. (2022). Analysis of needs for the development of ethnomathematic e-modules based on Riau Malay culture to facilitate mathematic literature ability of SMA/MA students. *Jurnal Pendidikan Matematika Dan IPA*, *13*(2), 244. https://doi.org/10.26418/jpmipa.v13i2.50396

De Vita, M., Verschaffel, L., & Elen, J. (2014). Interactive whiteboards in mathematics teaching: a literature review. *Education Research International*, *2014*, 1–16. https://doi.org/10.1155/2014/401315

Febrian, F., Astuti, P., & Antika, R. (2019). Pelatihan pengembangan media videoscribe dengan konteks lokal dalam mengajarkan objek matematika bagi MGMP SMA Kabupaten Bintan. *Jurnal Pengabdian Kepada Masyarakat*, *3*(101–110).

Gerakan Literasi Nasional. (2017). *Materi Pendukung Literasi Numerasi*. Jakarta: Kementerian Pendidikan dan Kebudayaan.

Guan, N., Song, J., & Li, D. (2018). On the advantages of computer multimedia-aided english teaching. *Procedia Computer Science*, *131*, 727–732. https://doi.org/https://doi.org/10.1016/j.procs.2018.04.317

Handayani, S. (2018). Development of interactive multimedia learning media to improve counting ability group students A TK Dharma Wanita Batursari. *Journal of Curriculum Indonesia*. Retrieved from http://hipkinjateng.org/jurnal/index.php/jci/article/view/6%0Ahttp://hipkinjateng.org/jurnal/index.php/jci/article/viewFile/6/11

Indriani, M. N., & Imanuel, I. (2018). Pembelajaran matematika realistik dalam permainan edukasi berbasis keunggulan lokal untuk membangun komunikasi matematis. *PRISMA, Prosiding Seminar Nasional Matematika*, *1*, 256–262.

Inovasi. (2019). *Numerasi Dasar: Membangun Fondasi Belajar Siswa*. Jakarta: Pusat Penelitian Kebijakan Pendidikan dan

Kebudayaan.

Irawan, A., Lestari, M., Rahayu, W., & Dwitiyanti, N. (2022). Developing a mathematics learning application using an android-based ethnomathematics concept of traditional javanese batik pattern. *KnE Social Sciences*. https://doi.org/10.18502/kss.v7i14.11965

Jamil, A. F., & Khusna, A. H. (2021). Pengembankan asesmen berorientasi kontekstual untuk meningkatkan kemampuan literasi matematis dan numerasi mahasiswa. *Jurnal Ilmiah Mandala Education*, *7*(4), 78–86.

Jiang, Z., Mok, I. A. C., & Yin, H. (2021). The relationships between teacher emotions and classroom instruction: Evidence from senior secondary mathematics teachers in China. *International Journal of Educational Research*, *108*(April), 101792. https://doi.org/10.1016/j.ijer.2021.101792

Kamsurya, R., & Masnia, M. (2021). Desain pembelajaran dengan pendekatan matematika realistik menggunakan konteks permainan tradisional dengklaq untuk meningkatkan keterampilan numerasi siswa sekolah dasar. *Jurnal Ilmiah Mandala Education*, *7*(4).

Kementerian Pendidikan dan Kebudayaan. (2017). *Gerakan Literasi Nasional Materi Pendukung Literasi Numerasi*. Jakarta: Tim Gerakan Literasi Nasional.

Kurnia, L., Azmi, R. D., Yuberta, K. R., Maris, I. M., & Apriliani. (2022). Development of ethnomathematics module using blended learning for undergraduate students. *AIP Conference Proceedings*, *2524*(1), 020004. https://doi.org/10.1063/5.0112553

Legesse, M., Luneta, K., & Ejigu, T. (2020). Analyzing the effects of mathematical discourse-based instruction on eleventh-grade students' procedural and conceptual understanding of probability and statistics. *Studies in Educational Evaluation*, *67*(January), 100918. https://doi.org/10.1016/j.stueduc.2020.100918

Mayer, R. E. (2014). *Multimedia Instruction. In J.M. Spector, M.D. Merrill, J. Elen, M.J. Bishop (Eds.), Handbook of research on educational communications and technology*. New York: Springer.

Miller, T. (2018). Developing numeracy skills using interactive technology in a play-based learning environment. *International Journal of STEM Education*, *5*(1), 39. https://doi.org/10.1186/s40594-018-0135-2

Nieveen, N. (1999). Prototyping to reach product quality. *Design Approaches and Tools in Education and Training, Springer*, 125–135.

Nurfatanah, N., Yudha, C. B., Marini, A., & Sumantri, M. S. (2021). Development of matemathic media games education based on e-learning in the planting of basic concepts in numeracy. *Journal of Physics: Conference Series*, *1869*(1), 012127. https://doi.org/10.1088/1742-6596/1869/1/012127

Nusir, S., Alsmadi, I., Al-Kabi, M., & Sharadgah, F. (2012). Studying the impact of using multimedia interactive programs at children ability to learn basic math skills. *Acta Didactica Napocensia*, *5*(2), 17–32.

OECD. (2016). *Results from PISA 2015: Indonesia*. *OECD Publishing*. Retrieved from https://www.oecd.org/pisa/PISA-2015-Indonesia.pdf

OECD. (2019). *Results from PISA 2018: Indonesia*. *OECD Publishing*. https://doi.org/10.1007/978-94-6209-497-0_69

Plomp, T. (2013). *Educational Design Resesarch: An Introduction. Dalam J. Van den Akker et al. Educatioan Design Research*. Enschede, Netherland: National Institute for Curriculum Development.

Priyani, N. E. (2022). Pengembangan literasi numerasi berbantuan aplikasi etnomatematik puzzle game pada pembelajaran matematika di sekolah perbatasan. *Jurnal Didaktika Pendidikan Dasar*, *6*(1), 267–280. https://doi.org/10.26811/didaktika.v6i1.536

Rohendi, D. (2019). Game-based multimedia for horizontal numeracy learning. *International Journal of Emerging Technologies in Learning*, *14*(15).

Rohendi, D., Sumarna, N., & Sutarno, H. (2017). Game multimedia in numeracy learning for elementary school students. *IOP Conference Series: Materials Science and Engineering*, *180*, 012068. https://doi.org/10.1088/1757-899X/180/1/012068

Russo, J., Bobis, J., Sullivan, P., Downton, A., Livy, S., McCormick, M., & Hughes, S. (2020). Exploring the relationship between teacher enjoyment of mathematics, their attitudes towards student struggle and instructional time amongst early years primary teachers. *Teaching and Teacher Education*, *88*, 102983. https://doi.org/10.1016/j.tate.2019.102983

Safitri, A. W., Pujiastuti, H., & Sudiana, R. (2020). Pengembangan game edukasi dengan konteks kearifan lokal Banten pada materi matriks. *Journal of Medives: Journal of Mathematics Education IKIP Veteran Semarang*, *4*(2), 319–328. https://doi.org/https://doi.org/10.31331/medivesveteran.v4i2.1171

Salsabila, N. H., Hapipi, H., & Lu'luilmaknun, U. (2021). Game-based learning media for number topic: analysis and design. *Jurnal Pendidikan Matematika*, *8*(2), 13–25. https://doi.org/https://dx.doi.org/10.18592/jpm.v8i2.5749

Salsabila, N. H., & Setyaningrum, W. (2018). Game "STATIC": Is it interesting for students? *Journal of Physics: Conference Series*, *1097*. https://doi.org/10.1088/1742-6596/1097/1/012105

Salsabila, N. H., & Setyaningrum, W. (2019). Pengembangan media pembelajaran matematika berbasis game: statistics in arctic. *Mandalika Mathematics and Educations Journal*, *1*(1), 13–25. https://doi.org/https://doi.org/10.29303/jm.v1i1.1248

Salsabila, N. H., & Setyaningrum, W. (2020). Game "STATIC": Is it effective for students' conceptual understanding? *Journal of Physics: Conference Series*, *1581*. https://doi.org/10.1088/1742-6596/1581/1/012065

Ulusoy, F. (2020). Prospective teachers' skills of attending, interpreting and responding to content-specific characteristics of mathematics instruction in classroom videos. *Teaching and Teacher Education*, *94*, 103103. https://doi.org/10.1016/j.tate.2020.103103

Widoyoko, E. P. (2016). *Evaluasi Program Pembelajaran*. Yogyakarta: Pustaka Pelajar.

Yunarti, T., & Amanda, A. (2022). Pentingnya kemampuan numerasi bagi siswa. *Prosiding Seminar Nasional Pembelajaran Matematika, Sains Dan Teknologi*, *2*, 44–48.

JMETP

Journal for the Mathematics Education and Teaching Practices, 3(2), 111-123, Dec 2022
e-ISSN: 2717-8587
dergipark.org.tr/jmetp

Young Wise Publishing
youngwisepub.com
© 2022

Research Article

Story problems created by elementary mathematics teacher candidates in real-life situations: an algebra learning area example*

Deniz Kaya[1], and Bahar Dincer[2]

Department of Mathematics and Science Education, Faculty of Education, Nevşehir Hacı Bektaş Veli University, Nevşehir, Turkey

Article Info

Received: 15 November 2022
Accepted: 26 December 2022
Available online: 30 Dec 2022

Keywords:
Algebra learning
Real-life
Story problem

Abstract

This research aims to examine the story problems of elementary mathematics teacher candidates in the field of algebra, which are suitable for real-life situations. For this purpose, it was tried to determine the pre-service teachers' preferred grade level, sub-learning area, and outcomes while creating a real-life story problem for the field of algebra learning. In addition, the relationship between story problems and outcomes, the reasons for choosing the grade level and sub-learning area, and the issues they paid attention to while creating the story problems are among the questions sought to be answered in the research. The research was designed according to the case study model. The study group the research consists of 35 elementary mathematics teacher candidates studying at the undergraduate level. 57% of the participants are female, and 43% male teacher candidates. In the study group selection, a non-random convenient sampling method was preferred. The algebra study instruction developed by the researchers was used as a data collection tool. In addition to the outcome(s) in the field of algebra learning, there are some questions that the participants should answer in the study guide. Descriptive and content analysis were used in the analysis of the data. According to the findings, most pre-service teachers were at the eighth-grade level, and inequalities created story problems suitable for a real-life situation related to the sub-learning domain. Pre-service teachers gave place to technology association in story problems. The pre-service teachers stated that they aimed to attract the students' attention and make them love mathematics while creating story problems. While creating the story problems, the most attention was paid to using actual data and originality. It has been suggested to increase pre-service teachers' awareness about the algebra learning field and encourage them to pose problems by the nature of their daily life situations.

To cite this article

Kaya, D., & Dincer, B. (2022). Story problems created by elementary mathematics teacher candidates in real-life situations: an algebra learning area example. *Journal for the Mathematics Education and Teaching Practices, 3*(2), 111-123.

Introduction

In our century, problem-solving skills are considered important in mathematics and all other disciplines. When we look at the teaching methods of the twenty-first century, problem-solving is in the first place. Therefore, increasing success in problem-solving is a subject that many educators and psychologists have researched. The student can easily express their thoughts and reasoning in the problem-solving process and see the missing or empty parts in the mathematical reasoning of others (Ministry of National Education [MoNE], 2018). In this respect, problem-based teaching is considered

[1] Corresponding Author: Nevşehir Hacı Bektaş Veli University, Faculty of Education, Department of Mathematics and Science Education, Department of Mathematics Education, Turkey. E-mail: denizkaya@nevsehir.edu.tr, ORCID No: 0000-0002-7804-1772

[2] İzmir Demokrasi University, Faculty of Education, Department of Mathematics and Science Education, Department of Mathematics Education, Turkey. E-mail: bahar.dincer@idu.edu.tr, ORCID No: 0000-0003-4767-7791

* This study was presented as an oral presentation at the 3rd International Congress on Gifted Youth and Sustainability of the Education

necessary for student cognitive development. Mathematics is an effective problem-solving tool that helps people understand their environment (Baykul, 2016). The use of problems in mathematics has similar reasons, such as drawing attention to the subject, making students eager, and evaluating students (Posamentier & Krulik, 2016). In general terms, the concept of a problem is a complex or uncertain question. The problem is a matter of research, discussion, or thinking (Van de Walle et al., 2013). That is, problems are necessary and essential for mathematics and daily life (Yazgan & Arslan, 2017). Studies on elementary mathematics programs and standards for assessing mathematics outcomes emphasized developing mathematical problem-solving and reasoning skills. One of the primary goals is to use these skills in solving real-life problems. Problem-solving is very important for mathematics applications and other disciplines. Students must develop their problem-solving skills to understand mathematical processes, steps, and operations and use their mathematical skills (Polya, 1981). For this reason, students need to have sufficient problem-solving skills to become competent in the discipline they are interested in (Chapman, 2006). Thanks to the problem-solving skill, which is one of the skills that is frequently emphasized among 21st-century skills, the skills of individuals such as creativity, critical thinking, questioning, reflective thinking, scientific thinking, high-level thinking, reasoning, and decision-making are also developed (National Research Council [NRC], 2012). In this respect, problem-solving is considered one of the essential components of mathematics education and is both the aim of learning mathematics and the fundamental part of the learning process (Baykul, 2020; Jonassen, 2000; Williams, 2003). One of the skills planned to be acquired by individuals in the Ministry of National Education Mathematics Curriculum is that individuals are effective problem solvers (MoNE, 2018).

Problem-posing skills are just as critical as problem-solving. Problem posing is defined as generating a new question based on a situation or creating a new question by changing a problem (Silver, 1997). Problem-posing is an essential element of applied and abstract mathematics. In addition, problem-posing is a part of the mathematical modeling of real-life situations (Christou et al., 2005; NRC, 2012). It is strongly recommended to include problem-posing activities in mathematics curriculum and classroom teaching (Brown & Walter, 1993; Silver, 1997). The importance of the subject is also emphasized in national sources, and it is recommended that students work on problem-posing activities in the new mathematics curriculum (MoNE, 2018). The basic philosophy underlying these suggestions is that problem-posing activities allow the association of concepts and operational processes. In addition, problem-posing allows for establishing relationships between mathematics, other disciplines, and real-life. In addition to all its positive features, it is stated that problem-posing activities contribute to the development of students' creative and flexible thinking abilities and problem-solving competencies (NRC, 2012). It is also known that problem-posing paves the way for students to develop a more realistic idea about mathematics and allows them to reinforce and enrich their past knowledge (English, 1997).

While deciding the content of this research, studies in the literature were also examined. It has been seen in the literature that there are studies examining the problem-posing skills of students. Studies examining problem-posing competencies have shown that most students of all ages and education levels need to be more successful in problem-posing activities (Crespo & Sinclair, 2008; Dede & Yaman, 2005; Stickles, 2011). It has been determined that the students must be sufficient to create questions that involve creative and critical thinking and require knowledge transfer between subjects and disciplines. It has been reported that they create routine questions that can be solved by applying rote information and rules rather than quality problems (Crespo & Sinclair, 2008). In a different study, it was found that pre-service teachers had difficulties in creating new questions. It was stated that this inadequacy was due to the participants' inexperience in problem-posing and their lack of knowledge (Stickles, 2011). Crespo and Sinclair (2008) also examined the problem-posing competencies of teacher candidates. The results showed that most of the generated problems were routine problems related to formula usage. It was observed that very few participants could pose problems that required analysis and synthesis. Studies conducted in our country have also revealed similar results. For example, Korkmaz and Gür's (2006) study showed that high school mathematics and primary school teaching department students produced questions similar to the four operation problems in mathematics textbooks. In other words, in that study, it was stated that pre-service teachers could not display the mathematical thinking and reasoning skills expected of them. In another study, it was seen that the participants were unsuccessful in problem-posing activities. It has been seen that the problems created are routine questions that contain quantitative data and are far from originality and creativity. Findings indicated that teacher candidates' inability to pose problems might be based on pedagogy (Bayazit & Kırnap-Dönmez, 2017). In another study conducted by Işık and Kar (2012), it was determined that the types of problems associated with different mathematical concepts and expressions given by students were limited, and problems that could be solved with simple calculations were preferred more. Students' performance in algebra learning is as essential as their problem-solving skills. Similarly, in the study by Dede and Yaman (2005), it was determined that pre-service mathematics teachers had difficulties in posing new problems based on the given problems and solutions. The study by Tekin-Sitrava and Işık (2018) concluded that the pre-service teachers who wrote verbal equations and could not pose any problems did not have sufficient content knowledge, problem-solving experience, and creativity skills. Algebra is the fundamental element of mathematics. In this respect, students' success in learning algebra profoundly affects mathematics and other fields. In addition to being a guide to understanding algebra problems, it is an effective communication tool to understand better and make sense of mathematics, an important subject area that performs actions on quantities, and a mathematical language that helps to understand symbolic representations (Akkaya & Durmuş, 2006; Kaput, 2008; Katz & Barton, 2007; Kieran, 2014; Lew, 2004; Stacey & MacGregor, 1999; Sutherland & Rojano, 1993). Therefore it is precious to make algebra more understandable and accessible for students (Kaput, 2008; Kieran, 2014). The findings of many studies in the related literature show that students have difficulties in understanding algebra (Akkan et al., 2017; Dede, 2004; Kar et al., 2011; Kaya, 2018; Kinzel, 2000; Stacey & MacGregor, 1999). The concepts in the algebra standard constitute the essential components of the school mathematics curriculum and help the concepts to be integrated (National Council of Teachers of Mathematics, [NCTM], 2000). However, the algebra learning field requires abstract thinking. In particular, having the expression unknown (variable) sometimes requires an understanding of abstract thinking in algebra because it contains expressions such as an equation and sometimes a figure, graph, diagram, table or picture.

Considering these inadequacies in problem posing, it is essential to carry out different studies and to provide training on this subject. It is known that education on problem-posing supports the development of pedagogical content knowledge and content knowledge (Silver, 1997). For this reason, including problem-posing activities in teacher education will contribute to the elimination of inadequacies in this regard. On the other hand, it may be beneficial for the training on this subject to include the skills to use the mathematical language effectively and to adapt the mathematical knowledge according to the student's cognitive levels. In this process, it is necessary to examine the characteristics and preferences of teacher candidates according to different variables to give practical problem-posing training. From this point of view, the researchers carried out this study. This study was planned to contribute to the literature and determine the problem-posing skills of teacher candidates in different subjects according to different variables. The field of algebra was chosen for this research on problem posing. Because no study has been found on this subject, this research aimed to examine the real-life story problems the elementary mathematics teacher candidates created for the field of algebra.

Problem of Research

This research aims to examine the story problems appropriate for real-life situations created by elementary mathematics teacher candidates for the field of algebra learning. The sub-problems of the research are as follows:

- What grade level, sub-learning area, and learning outcome(s) do pre-service teachers prefer while posing real-life story problems?
- What are the relationships between pre-service teachers' real-life story problems and the learning outcome(s)?
- What are the reasons why pre-service teachers prefer grade level and sub-learning areas?
- What points do pre-service teachers pay attention to when creating a story problem?

Method

Research Model

This research was designed in the case study model since it was aimed to examine the content of the story problems created by the elementary mathematics teacher candidates for the field of learning algebra. A case study is a methodological approach in which multiple data are collected to collect systematic information about how a limited system works (Chmiliar, 2010). Merriam (2013), on the other hand, defines a case study as an in-depth description and examination of a limited system. In short, the case study is a qualitative research approach in which the researcher examined one or more limited cases over time with data collection tools (observation, interviews, audio-visuals, documents, reports) that includes multiple sources and the themes related to the case(s) are defined (Creswell, 2018).

Participants

The study group of the research consists of 35 elementary mathematics teacher candidates studying at a state university at the undergraduate level. 20 (57%) of the participants are female, and 15 (43%) are male students. In the study group selection, the non-random convenient sampling method was preferred. Among the reasons for choosing this way are that the sample to be applied is studying in the mathematics education department of the university where the researcher is working, the ease of access to the sample, and the ease of time and labor. Appropriate sampling method; The sample is chosen from easily accessible and functional units due to limitations in terms of time, money, and labor (Büyüköztürk et al., 2018). Before the research was conducted, the participants were given detailed information about the content of the study. Participation in the research was based on volunteerism.

Data Collection Tools

In the study, a study guide prepared by the researchers for the field of algebra learning was used as a data collection tool. The opinions of the assessment and evaluation expert and the field expert were also taken in creating the content of the study directive. In this way, internal validity was tried to be ensured in preparing the study instructions. In the preparation of the study guide, first of all, the relevant literature was scanned, and the data collection tools and processes of studies conducted in a similar direction were carefully read (Akkan et al., 2019; Bayazit & Kırnap-Dönmez, 2017; Gainsburg, 2008; Güner, 2021; Güner & Erbay, 2021; Işık & Kar, 2012; Korkmaz & Gür, 2006; Lee, 2012; Özgeldi & Osmanoğlu, 2017; Özgen et al., 2017). In the study guide, which was prepared with the support of the literature, there are some topics the participants should answer and points to which the participants should pay attention. The study directive includes the outcomes at the sixth, seventh and eighth grades in the algebra learning field in the mathematics curriculum. Since there is no algebra learning area in the mathematics curriculum at the fifth-grade level, the outcomes at the sixth, seventh and eighth-grade levels were included in the study (MoNE, 2018). There are algebraic expressions at the sixth-grade level, algebraic expressions, equality and equations at the seventh-grade level, and algebraic expressions and identities, linear equations, and inequalities at the eighth-grade level (see Appendix-1). The headings in the study guide are as follows: (i) grade level, (ii) sub-learning area, (iii) outcome(s), (iv) why this grade level and the sub-learning area is preferred, (v) when creating story problems what is paid attention to and (vi) creating the story problem appropriate to the daily life situation. In the study, the names of the prospective teachers were kept confidential, and the study instructions were coded as TC1, TC2, TC3...TC35. In addition, to avoid bias, the answers given by the participants were given codes and reported in the findings section.

Analysis of Data

Qualitative data analysis was used to analyze the data in the research. Qualitative data analysis is an exploratory process, and in this process, the researcher organizes, classifies, synthesizes, draws patterns, reaches concepts, and reports the findings (Gürbüz & Şahin, 2016). In this study, the documents belonging to the problems that the students posed about the learning field of algebra were analyzed, and the obtained data were presented under specific categories. The data obtained from the problem-posing practices were analyzed with descriptive and content analysis methods. Descriptive analysis is analytical approach that includes the steps of processing qualitative data, defining the findings, and interpreting the identified findings depending on a predetermined framework (Yıldırım & Şimşek, 2018). Content analysis, on the other hand, requires an in-depth analysis of the collected data and allows the revealing of previously themes and dimensions (Yıldırım & Şimşek, 2018). Before proceeding to the data analysis, the researchers read the documents consisting of the data set several times. After this stage, first of all, the problems posed by the pre-service teachers in the real-life situation were examined by making content analysis. The content analysis aims to reach concepts and relationships that can explain the collected data. In another step, the percentages of preference (class, sub-learning domains, and outcome(s)) of previously given outcomes according to grade levels were evaluated with the help of descriptive analysis. While the outcomes are coded in the tables, they are specified as grade level, learning area, sub-learning area, and acquisition number, respectively. For example, the code [6.2.1.1] was used to acquire "writes an algebraic expression suitable for a verbally given situation and a verbal situation suitable for a given algebraic expression," which is included in the algebraic expressions sub-learning of the sixth-grade algebra learning domain. The order of the mathematics curriculum outcomes was considered in the formation of this code (MoNE, 2018).

Results

In this part of the research, the findings obtained in line with the sub-problems of the research are included. In this context, the story problems created by the participants by the actual life situation, grade level, sub-learning area, and learning outcomes were examined. Afterwards, the relationships between the story problems and the outcome(s) suitable for the real-life situation of the pre-service teachers were examined. In the other step, the reasons for preferring the pre-service teachers' grade level and sub-learning area were evaluated. Finally, the points that pre-service teachers paid attention to while creating a story problem were determined and reported. In this direction, what are the grade level, sub-learning area, and outcome(s) preferred by the pre-service teachers? Which is the first sub-problem of the research when creating story problems suitable for real-life situations? The findings regarding the problem are presented in the table below (Table 1).

Table 1. The story problem preferences of the participants appropriate to the real-life situation

Grade Level	Sub-Learning Area	Outcome Code	*f* (%)
6. Class	Algebraic Expressions	6.2.1.1	2 (%4.5)
		6.2.1.2	2 (%4.5)
7. Class	Algebraic Expressions	7.2.1.1	2 (%4.5)
		7.2.1.2	2 (%4.5)
		7.2.1.3	2 (%4.5)
	Equality and Equation	7.2.2.1	2 (%4.5)
		7.2.2.2	2 (%4.5)
		7.2.2.3	2 (%4.5)
		7.2.2.4	4 (%9.1)
8. Class	Algebraic Expressions and Identities	8.2.1.2	1 (%2.3)
		8.2.1.3	1 (%2.3)
	Linear Equations	8.2.2.1	2 (%4.5)
		8.2.2.2	1 (%2.3)
		8.2.2.3	1 (%2.3)
		8.2.2.5	4 (%9.1)
	Inequalities	8.2.3.1	7 (%16.0)
		8.2.3.3	7 (%16.0)

Note: There are studies in which more than one outcome is preferred

When Table 1 is examined, it was seen that the pre-service teachers preferred the eighth-grade level more while creating a real-life story problem related to the learning field of algebra. Especially at the eighth-grade level, inequalities created more story problems related to sub-learning. In addition, more story problems were created with linear equations in the eighth-grade and the sub-learning areas of equality and equations in the seventh-grade. The least preferred grade level was the sixth-grade level. The findings, which include the relationship between the story problems that the pre-service teachers set up in real-life about the algebra learning field and the achievements, are presented in the table below (Table 2).

Table 2. Relationships between real-life story problems and outcome(s)

Grade Level	Outcome Code	Story Problem Fiction
6. Class	6.2.1.1	Coins in the Piggy Bank (TC1) (Savings/Finance)
		Walnut Account (TC10) (Food)
	6.2.1.2	Height Growth (TC25) (Physical Development)
		Bone Age-Length (TC35) (Physical Development)
7. Class	7.2.1.1	Sapling Growth (TC34) (Plant Science)
		Computer Game (TC12) (Technology)
	7.2.1.2	Why Are Honeycombs Hexagonal? (TC7) (Animal Science)
		Erosion (TC11) (Natural Phenomenon)
	7.2.1.3	Fishing Boat (TC21) (Commercial)
		Paper Consumption (TC31) (Consumption)
	7.2.2.1	Well (TC22) (Human-Drilled Pit)
		Feast of Sacrifice (TC19) (Religious Feast)
	7.2.2.2	Paper Consumption (TC31) (Consumption)
		Bank Account (TC24) (Finance)
	7.2.2.3	Paper Consumption (TC31) (Consumption)
		Metaverse (TC16) (Technology)
		Video Watch Time (TC17) (Technology)
		Cinema Ticket (TC30) (Art)
	7.2.2.4	Local Election (TC29) (Politics)
		Bookcase (TC26) (Carpenter)
8. Class	8.2.1.2	EuroLeague Basketball Tournament (TC4) (Sports)
		Battery Health (TC13) (Technology)
		Telephone Billing Tariff (TC2) (Technology/Savings)
		Endemic Study (TC6) (Plant Science)
	8.2.1.3	Can people with a license drive all vehicles? (TC28) (Official Document)
		Obesity (TC14) (Health)
		Water Bill (TC33) (Finance)
		Drone (TC27) (Technology)
		Water Consumption (TC15) (Consumption)
		Construction Machinery Rental (TC9) (Commercial)
		Speed Limit (TC32) (Rule)
	8.2.2.1	Water Bill (TC33) (Finance)
		Poplar Tree (TC18) (Plant Science)
		Construction Machinery Rental (TC9) (Commercial)
		Pocket Money (TC3)
	8.2.2.2	Cake Making (TC23) (Recipe)
	8.2.2.3	Receiving a Gift (TC5) (Special Day)
		Telephone Billing Tariff (TC2) (Technology/Savings)
	8.2.2.5	Land Parceling (TC8) (Part of Earth)
	8.2.3.1	Darts Tournament (TC20) (Tournament)
	8.2.3.3	Telephone Billing Tariff (TC2) (Technology/Savings)

Note: There are studies in which more than one outcome is preferred

When Table 2 is examined, the pre-service teachers mainly focused on the co-existence of technology and daily life while creating real-life story problems related to learning algebra. Pre-service teachers focused more on the daily life situations of mobile phones, drones, video, virtual world, and computer games in technology-related story problems. In addition, there are financial, health, savings, physical development, consumption, plant and animal science, special days and people, rules (traffic rules), sports (tournaments, etc.), water consumption, and commercial and artistic story problems. Examples of real-life appropriate story problems that pre-service teachers have set up in the field of learning algebra are presented below.

According to a study based in the United States, people spend about 6 hours a day watching videos. Based on this result, we spend a lot of time watching videos. Thanks to the plug-in called "Video Speed Controller," you can adjust your time management by speeding up or slowing down the videos you watch during the day. Application controls are implemented very simply. Namely: The "X" key fast forwards the video we are watching by 10 seconds. The "Z" key rewinds the video we watch for 10 seconds. The "R" key increases the acceleration value of the video we watch by 0.4x. The "E" key increases the acceleration value of the video by 0.1x. The video acceleration value is initially fixed at "1.00x". The working principle of the application is simple. For example, if you want a video at 2.00x speed, then the player plays a two-second video in one second due to the value of 2.00x. Ali and his friend Kemal are watching videos using the application with the above features. When Ali starts watching the same video simultaneously, he presses the "x" key six times and the "R" key five times. Kemal, on the other hand, did not press the "x" and "z" keys; instead, he pressed the "R" critical 15 times. If Ali finished the video 10 seconds before Kemal, how long was the video they watched? (TC 17).

Water consumption is of great importance for a person to continue his life. According to the general guidelines of scientific organizations, it is stated that a healthy adult should consume at least 35 ml of water per kilogram of water per day. Water consumption helps individuals lose weight healthily, balance the metabolic rate, and prevent mineral loss in the body. How many liters of water do you consume per day? What is your weight? Can you calculate and express the amount of water consumption expressed according to the data of scientific organizations in direct proportion to your weight?... (TC15).

Beeswax production is a very energy-intensive process for bees. Bees use the hexagon as the most suitable honeycomb shape to do this process, which requires energy most easily and robustly. This shape is ideal for storing the most honey with less material. Do you know how bees make honey? If honeycombs were not hexagons, what shape would they be? Why? (TC7).

In another step of the research, the reasons for the pre-service teachers' choice of grade level and sub-learning area were evaluated. Accordingly, the reasons that stand out from the answers of the pre-service teachers on the answer sheets are listed in the table below (Table 3).

Table 3. Reasons of participants preferring story problems

Reason for Preference	***f*** **(%)**
Attract students' attention	25 (%71.4)
Making students love math	23 (%65.7)
To be fun and intriguing	22 (%62.8)
Because it is learning that students have difficulty with	20 (%57.1)
As it forms the basis of other outcomes	15 (%42.8)
Because they are familiar with this outcome according to other outcome and grade level	13 (%37.1)
Because it allows more possibilities for multiple impressions	10 (%28.5)
Since the selected class level has preliminary information	9 (%25.7)
To avoid misconceptions	5 (%14.2)
Because it allows for more concretization	4 (%11.4)
Because it allows modeling	3 (%8.5)
Other reasons (more gains, lack of rote learning, etc.)	3 (%8.5)
8th graders will attend high school entrance exam and because there are so many questions about this subject	2 (%5.7)
No idea	1 (%2.8)

Note: There are studies in which more than one reason is presented

When Table 3 is examined, the pre-service teachers mostly set up real-life story problems with the thought that they would attract students' attention, make the love of mathematics, and be entertaining and intriguing. In addition, the fact that it is the learning area that students have the most difficulty with, and it forms the basis of other acquisitions, pre-service teachers' pre-dispositions, providing more opportunities for multiple demonstrations, and having prior knowledge of the chosen grade level are among the other reasons why pre-service teachers create story problems. The pre-service teachers' answers were to avoid misconceptions, make concretizations and model, and because the students took the exam at the end of the year, they preferred this story problem. The points that the pre-service teachers paid attention to while creating the story problem, which is another sub-problem of the research, are presented below in the form of a word cloud.

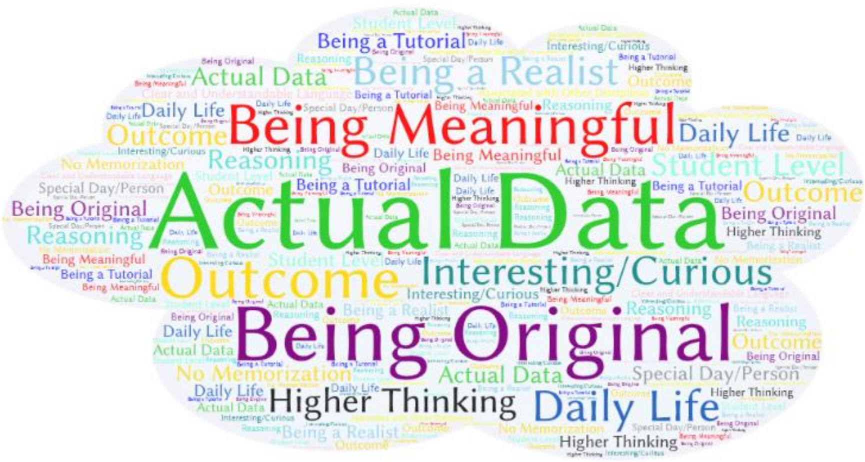


Figure 1. Considerations while creating the story problem

When Figure 1 is examined, it can be seen that the pre-service teachers use actual data (*n*=28), original (*n*=22), meaningful (*n*=21), achievements (*n*=20), compatible with daily life while creating story problems suitable for real-life situations. (*n*=19), realistic (*n*=18), interesting, attractive, and intriguing (*n*=15), high-level thinking skills (*n*=11), precise and clear (*n*=9), instructive (*n*=8), requiring reasoning (*n*=5), not being memorizing (*n*=3), being related to other disciplines (*n*=2), including special days and people (*n*=1).

Discussion and Conclusion

Within the scope of this research, the pre-service teachers' story problems set up by the actual life situation in the field of learning algebra were examined. In this context, pre-service teachers mostly preferred outcomes at the eighth-grade level while posing real-life story problems. At least the pre-service teachers posed a story problem in the eighth and sixth grades. Inequalities, linear equations, equality, and equation sub-learning areas come to the fore in the preferences of pre-service teachers in story problems. It is noteworthy that they set up more story problems related to the inequalities sub-learning domain. Among the most important reasons for this situation it can be shown that the subject of inequalities is more difficult for students to learn. Another reason is that eighth graders will take the entrance exam to high schools because questions about the field of algebra learning take an important place in the entrance exam to high schools. It has been determined that the pre-service teachers pay attention to the fact that the students have the necessary pre-knowledge about learning algebra to pose more story problems at the eighth-grade level. There are fewer acquisitions related to algebra learning in the mathematics curriculum, and the number of acquisitions increases as the grade level increases. Therefore, as the grade level of the student's increases, the intensity of their relationship with algebra also increases. This situation may have caused pre-service teachers to be more interested in the eighth-grade level while creating story problems. Considering the higher number of sub-learnings and the diversity of achievements, most pre-service teachers preferred the eighth-grade level. Creating more story problems, especially in the inequalities and linear equations sub-learning areas, can be the most substantial evidence of this situation.

Due to its structure, algebra requires abstract thinking (Stacey & MacGregor, 1999). At the same time, algebra is one of the essential fields of study in many disciplines, and being able to express ideas is an essential component of its nature. Algebra is an important field of study that should be known for using mathematical language effectively (Lew, 2004; Sutherland & Rojano, 1993). Algebra supports reasoning and plays an essential role in transforming numbers and symbols into equations (Akkaya & Durmuş, 2006; Katz & Barton, 2007). These strengths of algebra were also reflected in the pre-service teachers' story problems. It is seen that pre-service teachers also consider the student's prior knowledge in their preferences in story problems related to algebra learning. The findings of many studies in the related literature show that students have difficulties and difficulties in understanding algebra (Akkan et al., 2017; Dede, 2004; Kar et al., 2011; Kaya, 2018; Kinzel, 2000; Stacey & MacGregor, 1999).

Pre-service teachers also tried to present a different perspective on inequalities by posing more story problems about inequalities, one of the sub-learning areas where students have the most difficulty in algebra. It is known that there are problems both in teaching and in students' learning about inequalities (Çoban & Yenilmez, 2020). Therefore, the fact that the pre-service teachers gave more place to this subject in the content of the story problems shows that the pre-service teachers are also aware of the problems experienced in teaching inequalities. Another finding is that the pre-service teachers set up many real-life story problems for the seventh-grade level equality and equation sub-learning domain. The past learning experiences of the pre-service teachers can be shown as the reason for the tendency of the pre-service teachers at this grade level. The construction of the contents of the pre-service teachers' story problems is similar to the problems in the mathematics textbooks. In this context, while students are creating story problems, they are generally influenced by the textbooks and the situations that often occur in their lives. This finding shows parallelism with the result of a similar study in the literature (Korkmaz & Gür, 2006). In addition, there are study findings in the related literature that the story problems created by the students primarily reflect the content of the textbooks and consist of problems that do not include creativity (Bayazit & Kırnap-Dönmez, 2017).

Another study finding was that pre-service teachers prioritized combining technology and real life in story problems. Pre-service teachers gave space to technology-related information, which has an important place in our lives, in story constructions. Although this finding is an expected result, it also emphasizes the place of technology in our lives. Pre-service teachers discussed situations we frequently encounter daily, such as mobile phones, drones, videos, virtual worlds, and computer games. Considering the place of mobile phones and computers in our lives, it was inevitable that this situation would reflect on the problems of teacher candidates. However, although there are many tendencies to story problems related to technology, this number is not enough. Because considering the number of the participant group, it is seen that the number of technology and technology-related story problems is limited. Examining the findings of similar studies, it is noteworthy that students are not successful enough in problem-posing activities, are insufficient in knowledge transfer questions, and form questions based on rote (Crespo & Sinclair, 2008; Dede & Yaman, 2005; Stickles, 2006). In the findings of the study conducted by Işık and Kar (2012), it was determined that pre-service teachers preferred more problems that could be solved with simple calculations. Pre-service teachers' content knowledge, problem-solving experience, and creativity skills are essential to pose a good problem (Tekin-Sitrava & Işık, 2018). In addition to these, physical development (height growth, weight gain, etc.), finance/savings, food, plant and animal science (sapling, poplar, bee, etc.), natural events (erosion), consumption (paper and water consumption, etc.), Pre-service teachers also created story problems on religious holidays, art, politics (local elections), sports (basketball, darts, etc.), health (obesity) and rules (traffic rules).

Another finding from the research was the reasons why pre-service teachers preferred story problems. Pre-service teachers stated that they mostly acted to attract the students' attention while creating the story problems. It was stated that endearing mathematics and being intriguing are characteristic features of story problems. In addition, pre-service teachers' dispositions, being the basis of other acquisitions, subjects that students have difficulty with, allowing multiple demonstrations, lack of prior knowledge of the selected class, and allowing modeling are among the other reasons for their preference. At this point, pre-service teachers need to have problem-posing skills. In the study conducted by Dede and Yaman (2005), it was reported that students had difficulties posing new problems and that problem-posing was a critical skill component. The last finding of the study was obtained from the points that pre-service teachers paid attention to while creating story problems suitable for real-life situations. Accordingly, pre-service teachers paid attention to using actual data, originality, meaningfulness, achievements, compatibility with daily life, realistic, interesting, attractive, and intriguing while posing story problems. In addition, other issues were considered to include high-level thinking skills, being understandable and transparent, being instructive, requiring reasoning, not being memorized, being related to other disciplines, and including special days and people. While creating the story problems of the pre-service teachers, they generally tried to keep concretization in the foreground. It is emphasized that giving mathematical concepts to primary school students as concretely as possible will enable them to learn and understand advanced mathematical concepts (Akkan et al., 2017).

Recommendations

By increasing pre-service teachers' awareness about the field of learning algebra, they can be encouraged to pose problems appropriate to the nature of their daily life situation. In this study, the problem-posing skills of pre-service teachers in learning algebra were examined. Teachers' skills on this subject can be examined in future studies. In addition, pre-service teachers can be asked to pose more problems related to the learning area, problem-solving strategies, process skills, and contexts they prefer less, so they have a more comprehensive range of problem-posing skills. Within the scope of the study, only one learning area was considered. Therefore, similar studies can be conducted on learning areas in all grades (5, 6, 7, 8) in the mathematics curriculum. In addition to the story problem preferences of teacher candidates, the relationships between learning styles can be discussed and examined in depth. Problem posing is a situation that has an important place, especially in mathematics education, and requires expertise. In this regard, teacher candidates can be trained in this direction, and the content of elective courses can be arranged in this direction. In the study, which was designed by a real-life situation, only the learning areas and the achievements in these learning areas were given to the participants. In studies to be carried out in a similar direction, verbal problem sentences or equations may be given. They may be asked to set up story problems suitable for daily situations.

Limitation of Study

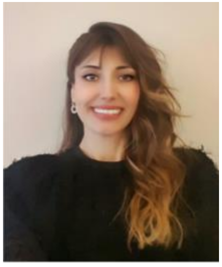
The most important limitation of the study is that only the algebra learning area is included in creating story problems. The algebra learning area in the mathematics curriculum is at the sixth, seventh, and eighth-grade levels. There is no algebra learning area at the fifth-grade level. Therefore, the sub-dimensions of the algebra learning field are limited to the sixth, seventh and eighth-grade levels. Another limitation of the study is the participation of volunteer students. The content of the story problems written by the students who did not want or could not participate in studying the real-life situation may vary. In addition, the study was carried out with undergraduate students in the last year. The story problems related to the algebra learning domain of students at different grade levels may also vary.

Acknowledgment

We would like to thank teacher candidates who participated in our study and answered the study instruction patiently and sincerely. We also want to acknowledge the reviewers from JMETP for their invaluable comments. The authors contributed equally to the study. The authors declare that they have no conflict of interest. All the rules in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" were followed in this research. None of the actions in "Ethics Actions Against Scientific Research and Publication " were carried out.

Biodata of the Authors

Asst. Prof. Dr. **Deniz Kaya** completed his master's and doctorate in Dokuz Eylül University Institute of Educational Sciences, Mathematics Education. He continues his academic life at Faculty of Education in the Department of Mathematics and Science Education in Nevşehir Hacı Bektaş Veli University. His research interest includes visualizing the concepts images, educational technology, mathematical connection, flipped learning, algebraic thinking, and mathematical modelling in mathematics education. Affiliation: Department of Mathematics and Science Education, Faculty of Education, Nevşehir Hacı Bektaş Veli University. E-mail: denizkaya@nevsehir.edu.tr, ORCID: 0000-0002-7804-1772



Asst. Prof. Dr. **Bahar Dincer** completed master's and doctorate in Dokuz Eylül University Institute of Educational Sciences, Mathematics Education. She continues her academic life at Faculty of Education in the Department of Mathematics and Science Education in İzmir Demokrasi University. Her doctoral thesis was on concept learning with storytelling. She has been working on designing learning in context, mathematics teaching, concept and process theory. Affiliation: Department of Mathematics and Science Education, Faculty of Education, İzmir Demokrasi University. E-mail: bahar.dincer@idu.edu.tr, ORCID: 0000-0003-4767-7791

References

Akkan, Y., Öztürk, M., Akkan, P., & Küçük-Demir, B. (2019). Ortaokul matematik öğretmenlerinin aritmetik ve cebir problemleri hakkındaki inanışları [Opinions and beliefs of middle school mathematics teachers about arithmetic and algebra problems] *Erzincan University Journal of Education Faculty, 21*(1), 156-176. https://doi.org/10.17556/erziefd.431583

Akkan, Y., Akkan, P., & Güven, B. (2017). Aritmetik ve cebir kavramları ile ilgili farkındalık [Awareness of arithmetic and algebra concepts]. *Journal of Bayburt Education Faculty, 12(*24), 527-558.

Akkaya, R., & Durmuş, S. (2006). İlköğretim 6-8. sınıf öğrencilerinin cebir öğrenme alanındaki kavram yanılgıları [Misconceptions of elementary school students in grades 6-8 on learning algebra]. *Hacettepe University Journal of Education, 31,* 1-12.

Bayazit, İ., & Kırnap-Dönmez, S. M. (2017). Prospective teachers' proficiencies at problem posing in the context of proportional reasoning. *Turkish Journal of Computer and Mathematics Education, 8*(1), 130-160. https://doi.org/10.16949/turkbilmat.303759

Baykul, Y. (2020). Matematik öğretimi [Mathematics teaching] (4th ed.). Pegem Academy. https://doi.org/10.14527/9786053-646754

Baykul, Y. (2016). *İlkokulda matematik öğretimi [Teaching mathematics in primary school]* (13th ed.). Pegem Academy.

Brown, S. I., & Walter, M. I. (Eds.). (1993). *Problem posing in mathematics education.* Lawrence Erlbaum Associates.

Büyüköztürk, S., Çakmak, E. K., Akgün, O. E., Karadeniz, S., & Demirel, F. (2018). *Bilimsel araştırma yöntemleri [Scientific research methods in education]* (25th ed.). Pegem Academy. https://doi.org/10.14527/9789944919289

Chapman, O. (2006). Classroom practices for context of mathematics word problems. *Educational Studies in Mathematics, 62,* 211-230. https://doi.org/10.1007/s10649-006-7834-1

Chmiliar, I. (2010). Multiple-case designs. In A. J. Mills, G. Eurepas & E. Wiebe (Eds.), *Encyclopedia of case study research* (pp. 582-583). Sage Publication.

Christou, C., Mousoulides, N., Pittalis, M., Pitta-Pantazi, D., & Sriraman, B. (2005). An empirical taxonomy of problem posing processes. *Zentralblatt füur Didaktik der Mathematik, 37*(3), 149-158. https://doi.org/10.1007/s11858-005-0004-6

Crespo, S., & Sinclair, N. (2008). What makes a problem mathematically interesting? Inviting prospective teachers to pose better problems. *Journal of Mathematics Teacher Education, 11*(5), 395-415.

Creswell, J. W. (2018). *Nitel araştırma yöntemleri. Beş yaklaşıma göre nitel araştırma ve araştırma deseni [Qualitative research methods. Qualitative research and research design according to five approaches]* (M. Bütün & S. B. Demir, Trans.) (4th ed.). Siyasal Bookstore.

Çoban, K., & Yenilmez, K. (2020). Sekizinci sınıf öğrencilerinin eşitsizlikler konusunda karşılaştıkları güçlüklerin incelenmesi [Investigation of the difficulties encountered by eighth grade students on inequalities]. *Journal of Education in Eskişehir Osmangazi University Turkic World Apply and Research Center, 5*(1), 40-56.

Dede, Y., & Yaman, S. (2005). Matematik öğretmen adaylarının matematiksel problem kurma ve problem çözme becerilerinin belirlenmesi [Identification of mathematical problem posing and problem solving skills for prospective mathematics teachers]. *Eurasian Journal of Educational Research, 18,* 41-56.

Dede, Y. (2004). Öğrencilerin cebirsel sözel problemleri denklem olarak yazarken kullandıkları çözüm stratejilerinin belirlenmesi [Identifying students' solution strategies in writing algebraic word problem as equations]. *Educational Sciences and Practice, 3*(6), 175-192.

English, L. D. (1997). The development of fifth-grade children's problem-posing abilities. *Educational Studies in Mathematics, 34,* 183-217. https://doi.org/10.1023/A:1002963618035

Gainsburg, J. (2008). Real-world connections in secondary mathematics teaching. *Journal of Mathematics Teacher Education, 11*(3), 199-219. https://doi.org/10.1007/s10857-007-9070-8

Güner, P., & Erbay, H. N. (2021). Metacognitive skills and problem-solving. *International Journal of Research in Education and Science, 7*(3), 715-734. https://doi.org/10.46328/ijres.1594

Güner, P. (2021). Problem-posing skills and thinking styles of preservice teachers. *HAYEF: Journal of Education, 18*(2), 254-277. https://doi.org/10.5152/hayef.2021.21003

Gürbüz, S., & Şahin, F. (2016). *Sosyal bilimlerde araştırma yöntemleri: Felsefe-yöntem-analiz [Research methods in social sciences: Philosophy-method-analysis]* (3th ed.). Seçkin Publishing.

Işık, C., & Kar, T. (2012). Sınıf öğretmeni adaylarının problem kurma becerileri [Pre-service elementary teachers' problem posing skills]. *Journal of Mehmet Akif Ersoy University Faculty of Education, 23,* 190-214.

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development, 48*(4), 63-85. https://doi.org/10.1007/BF02300500

Kaput, J. J. (2008). What is algebra? What is algebraic reasoning? In J. J. Kaput, D. W. Carraher, & M. L. Blanton (Eds.), *Algebra in the early grades* (pp. 5-17). Lawrence Erlbaum Associates.

Kar, T., Çiltaş, A., & Işık, A. (2011). Cebirdeki kavramlara yönelik öğrenme güçlükleri üzerine bir çalışma [A study on the learning difficulties for algebra concepts]. *Kastamonu Education Journal, 19*(3), 939-952.

Katz, V. J., & Barton, B. (2007). Stages in the history of algebra with implications for teaching. *Educational Studies in Math, 66*(2), 185-201. https://doi.org/10.1007/s10649-006-9023-7

Kaya, D. (2018). Yedinci sınıf öğrencilerinin cebirsel sözel problemleri çözme becerilerinin incelenmesi [Examination of seventh grade students' ability to solve algebraic verbal problems]. *Balıkesir University The Journal of Social Sciences Institute, 21*(39), 159-181. https://doi.org/10.31795/baunsobed.437730

Kieran, C. (2014). Algebra teaching and learning. In S. Lerman (Ed.), *Encyclopaedia of mathematics education* (pp. 27-32). Springer Publishing.

Kinzel, M. T. (2000). *Characterizing ways of thinking that underlie college students interpretation and use of algebraic notation* (Unpublished doctoral dissertation). The Pennsylvania State University.

Korkmaz, E., & Gür, H. (2006). Öğretmen adaylarının problem kurma becerilerinin belirlenmesi. [Determining of prospective teachers' problem posing skills]. *Balıkesir University Journal of Science Institute, 8*(1), 64-74.

Lee, J. E. (2012). Prospective elementary teachers' perceptions of real-life connections reflected in posing and evaluating story problems. *Journal of Mathematics Teacher Education, 15*(6), 429-452. https://doi.org/10.1007/s10857-012-9220-5

Lew, H. C. (2004). Developing algebraic thinking in early grades: Case study of Korean elementary school mathematics. *The Mathematics Educator, 8*(1), 88-106.

Merriam, S. B. (2013). *Nitel araştırma: Desen ve uygulama için bir rehber [Qualitative research: A guide to design and implementation]* (S. Turan, Trans.). Nobel Publishing.

Ministry of National Education (MoNE) (2018). *Matematik dersi öğretim programı (İlkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. sınıflar) [Mathematics lesson curriculum (primary and middle school 3, 4, 5, 6, 7 and 8th grades)].* Ankara: Ministry of National Education.

National Council of Teachers of Mathematics (NCTM) (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Research Council (NRC) (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century. J. W. Pellegrino & M. L. Hilton (Eds.).* The National Academies Press.

Özgeldi, M., & Osmanoğlu, A. (2017). Connecting mathematics to real-life: An investigation on how prospective secondary mathematics teachers build real-life connections. *Turkish Journal of Computer and Mathematics Education, 8*(3), 438-458. https://doi.org/10.16949/turkbilmat.298081

Özgen, K., Aydın, M., Geçici, M. E., & Bayram, B. (2017). Sekizinci sınıf öğrencilerinin problem kurma becerilerinin bazı değişkenler açısından incelenmesi [Investigation of problem-posing skills of eighth grade students in terms of some variables]. *Turkish Journal of Computer and Mathematics Education, 8*(2), 323-351. https://doi.org/10.16949/turkbilmat.322660

Polya, G. (1981). *Mathematical discovery: On understanding, learning, and teaching problem-solving.* John Wiley & Sons.

Posamentier, A., & Krulik, S. (2016). Effective techniques to motivate mathematics instruction. Routledge.

Silver, E. A. (1997). Fostering creativity through instruction rich in mathematical problem solving and problem posing. *Zentralblatt für Didaktik der Mathematik, 29*(3), 75-80. https://doi.org/10.1007/s11858-997-0003-x

Stacey, K., & MacGregor, M. (1999). Learning the algebraic method of solving problems. *The Journal of Mathematical Behavior, 18*(2), 149-167. https://doi.org/10.1016/S0732-3123(99)00026-7

Stickles, P. R. (2011). An analysis of secondary and middle school teachers' mathematical problem posing. *Investigations in Mathematics Learning, 3*(2), 1-34. https://doi.org/10.1080/24727466.2011.11790301

Sutherland, R., & Rojano, T. (1993). A spreadsheet approach to solving algebra problems. *The Journal of Mathematical Behavior, 12*(4), 353-383.

Tekin-Sitrava, R., & Işık, A. (2018). Sınıf öğretmeni adaylarının serbest problem kurma becerilerinin incelenmesi [An investigation into prospective primary school teachers' free problem posing skills]. *Gazi University Journal of Gazi Educational Faculty, 38*(3), 919-947.

Van de Walle, J. A., Karp, K. S., & Bay-Williams, J. M. (2013). *Elementary and middle school mathematics: Teaching developmentally* (8th ed.). Pearson Publishing.

Williams, K. M. (2003). Writing about the problem solving process to improve problem solving performance. *The Mathematics Teacher, 96*(3), 185-187.

Yazgan, Y., & Arslan, Ç. (2017). *Matematiksel sıradışı problem çözme stratejileri ve örnekleri [Mathematical unusual problem solving strategies and examples].* Pegem Academy.

Yıldırım, A., & Şimşek, H. (2018). *Sosyal bilimlerde nitel araştırma yöntemleri [Qualitative research methods in the social sciences]* (11th ed.). Seçkin Publishing.

Appendix-1: Mathematics Curriculum Algebra Learning Area Outcomes

Grade 6 Algebra Learning Field

Sub-Learning Area: Algebraic Expressions

6.2.1.1. Writes an algebraic expression suitable for a verbally given situation and a verbal situation suitable for a given algebraic expression.
6.2.1.2. Calculates the value of the algebraic expression for the different natural number values that the variable will take.
6.2.1.3. Explain the meaning of simple algebraic expressions.

Grade 7 Algebra Learning Field

Sub-Learning Area: Algebraic Expressions

7.2.1.1. Performs addition and subtraction operations with algebraic expressions.
7.2.1.2. Multiplies an algebraic expression by a natural number.
7.2.1.3. Expresses the rule of the number patterns with a letter and finds the desired term of the pattern whose rule is expressed with a letter.

Sub-Learning Area: Equality and Equation

7.2.2.1. Understand the principle of conservation of equality.
7.2.2.2. Recognizes an equation with a first-order unknown and establishes an equation with a first-degree unknown by given real-life situations.
7.2.2.3. Solves first-order equations with one unknown.
7.2.2.4. Solves problems that require establishing an equation with a first-order unknown.

Grade 8 Algebra Learning Field

Sub-Learning Area: Algebraic Expressions and Identities

8.2.1.1. Understands simple algebraic expressions and write them in different formats.
8.2.1.2. Multiplies algebraic expressions.
8.2.1.3. Explain identities with models.
8.2.1.4. Factors algebraic expressions.

Sub-Learning Area: Linear Equations

8.2.2.1. Solves first-order equations with one unknown.
8.2.2.2. It recognizes the coordinate system with its properties and shows ordered pairs.
8.2.2.3. Expresses how one of the two variables that have a linear relationship between them changes depending on the other, with a table and an equation.
8.2.2.4. Draws the graph of linear equations.
8.2.2.5. Creates and interprets equations, tables, and graphs of real-life situations with linear relationships.
8.2.2.6. Explain the slope of the line with models, and relate linear equations and graphs with the slope.

Sub-Learning Area: Inequalities

8.2.3.1. Writes mathematical sentences suitable for daily situations involving inequality with a first-degree unknown.
8.2.3.2. Represents inequalities with a first-order unknown on the number line.
8.2.3.3. Solves inequalities with a first-order unknown.

Journal for the

Mathematics Education and Teaching Pratices

Young Wise Publishing

ISSN: 2717-8870