# Developing Digital Simulation to Improve Students' Numeracy Skills

Wahyu Setyaningrum[1], Ariyadi Wijaya[1], Aan Nur Irsyad[1] and Mayang Purbaningrum[1]

[1] Mathematics Education Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Indonesia
wahyu_setyaningrum@uny.ac.id

**Abstract.** One way to improve numeracy is to use digital simulations that implement mathematics in real life. This research aims to develop a digital simulation to improve junior high school students' numeracy in statistics. The design of this research is Research and Development with a four-D model. This paper focuses on discussing the design of the simulation that could facilitate students' numeracy in 8th grade junior high school. There is one designed simulation, that is a science experiment simulation about heating water. This simulation uses uncertainty and data content as well as personal context. The main intention of the heating water simulation is to build students' ability to generate and process data and to make a mathematical model that fits the data. Apart from that, students are also asked to choose an appropriate diagram to present experimental data of the heating water. Concerning the cognitive level, both simulation covers applying and reasoning levels. From limited trials, the digital simulation of uncertainty and data that has been developed can support junior high school students' numeracy skills based on responses to the three tasks and student questionnaire responses. The development of digital simulations on statistical data presentation material will become a media reference for further digital simulation development and can be used by teachers to develop student numeracy.

**Keywords:** Digital simulation, Numeracy, Uncertainty and Data Content

## 1 Introduction

Responding to problems in an increasingly complex world, the OECD through the Program for International Student Assessment (PISA) aims to measure students' mastery in applying knowledge in various real-world situations. One of the abilities tested in PISA is mathematical literacy or what can be called numeracy. Differences in the use of mathematical literacy or numeracy appear to be based on geographic location. Some countries choose mathematical literacy, while others choose numeracy [1]. According to the OECD, mathematical literacy is a person's ability to reason mathematically and formulate, use, and interpret mathematics to solve problems in various real-world situations [2] In Indonesia, the term numeracy is used to describe the ability to think using concepts, facts, procedures, and mathematical tools to solve everyday problems in various contexts related to people in Indonesia and around the


P. C. Kuswandi et al. (eds.), *Proceedings of the 6th International Conference on Current Issues in Education (ICCIE) 2023*, Advances in Social Science, Education and Humanities Research 847,
https://doi.org/10.2991/978-2-38476-245-3_31

world [3]. Researchers use the term "numeracy" in this article because the research took place in Indonesia. One of the contents of numeracy is uncertainty and data. Studying uncertainty and data is very important for students because this topic is the core of mathematical analysis for various situations related to probability and statistics which are used as techniques for describing and representing data [2].

However, in PISA 2022, Indonesia received a numeracy score of 366 which decreased by thirteen points from PISA 2018 [4]. Several studies that have been carried out have also found low results in numeracy, especially for junior high school students [5], [6]. The low numeracy results are caused by various factors. Students who are not familiar with contextual problems will find it difficult to work on numeracy questions that are closely related to contextual problems [7]. This happens because students have difficulty modeling mathematics [7]. Students also find it difficult to present and interpret existing information [8]. It can be said that the low numeracy results of Indonesian students are because students are less accustomed to being exposed to real-life situations when learning mathematics.

Various ways to improve numeracy include using appropriate learning [9], [10]. Improving numeracy can also use tasks development, especially on data content and uncertainty [11], [12]. Apart from using learning or developing tasks, media development can also improve student numeracy [13], [14]. The existence of material prepared using media makes it easier for students to understand contextual problems presented in learning because it brings the abstract into concrete.

One way that can be chosen to increase students' numeracy regarding uncertainty and data content by using digital simulation. Simulations are closely aligned with reality design principles, creating environments that can be directly manipulated by students [15]. Digital simulations can make it easier for students to model real situations in mathematical form. The advantages of using simulations in learning is can simplify phenomena that occur so that they are easy to understand [16]. Simulation is needed in statistics which is closely related to the presentation and processing of data. The existence of simulations in statistics makes it easier for students to represent data and interpret data. One media that can be used for digital simulation is Desmos. Based on research that has been conducted, Desmos can increase student numeracy [17].

Currently, the use of digital simulations still limited in biology [18], chemistry [19], physics [20], and higher education [21]. For the use of digital simulations in mathematics learning is still limited to the involvement of seventh to tenth-grade students in studying general basic material about numbers, geometry, measurement, patterns, and algebra, as well as statistics and probability [29]. The low numeracy of students, especially in statistical data presentation, needs to be followed up, one of which is by using digital simulations that have not been empirically researched in junior high school students. This research aims to develop a digital simulation to improve junior high school students' numeracy skills. It is hoped that the development of digital simulations on statistical data presentation material will become a media reference for further digital simulation development and can be used by teachers to develop student numeracy.

## 2 Method

This research uses the Research and Development method because this research develops a product, namely digital simulation using the Desmos web. The development procedure in this research adheres to the 4-D (Four D) development model in Figure 1 based on Thiagarajan [30].

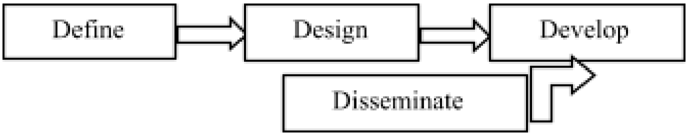



**Fig. 1.** Flow diagram 4-D model

(1) define which includes front-end analysis, learner analysis, concept analysis, task analysis, and specifying instructional objectives. (2) design includes preparing questionnaire criteria, media selection, format selection, and initial design of the Desmos web-based mathematics learning media to improve numeracy, (3) development, and (4) dissemination. This research focuses on digital simulation designs that can facilitate students' numeracy skills and determine student responses after using digital simulations. Student responses were obtained from limited trials. The population of this study was all eighth-grade students with total 210 students at one of the State Junior High Schools in Yogyakarta for the 2023/2024 academic year. The trial was carried out on 27 students randomly. The subjects consisted of 11 women and 16 men with range age 14-15. The characteristics of all classes homogeneous based on test scores that are not much different between students. The instruments used were open questionnaire in Google Form to determine student responses after using digital simulations and three tasks in simulation to know students' numeracy skills. The data obtained from this research was analyzed using qualitative descriptive. Data analysis steps are divided into data preparation, reading the information, data coding in likert scale, data presentation, and data interpretation [24].

## 3 Results and Discussion

Stages of the digital simulation media development process.

### 3.1 Define

Based on Thiagarajan [23], five activities appear at the define stage, namely:

**Front-end Analysis**. Numeracy is one of the basic abilities required by individuals. However, low results were obtained in student numeracy, especially in data content and uncertainty which is closely related to statistics. To improve students' numeracy, one way is to use digital simulations which make it easier for students to model mathematics.

**Learner Analysis**. Based on the results of the analysis of junior high school students, the majority already have smartphones. The technology used by teachers is still limited to the use of PowerPoint. Students adore to be involved in things related to technology. Media is needed that can be used on smartphones and requires student activity in its use.

**Concept Analysis**. Uncertainty and data are one of the contents with low achievement results but is very necessary to master. Therefore, this content was selected for the development of digital simulations.

**Task Analysis**. Numeracy tasks contained in digital simulations should be close to students' lives and appropriate to uncertainty and data content. The context chosen is a personal context with the topic of water heating experiments and the presentation of experimental data.

**Specifying Instructional Objectives**. The learning objectives that the teacher has designed become the basis for material analysis and task analysis to create digital simulations.

## 3.2 Design

Based on Thiagarajan [23], four activities appear at the design stage, namely:

**Preparation of Questionnaire Criteria**. A questionnaire was prepared to determine student responses after using the Desmos digital simulation. The questionnaire questions are structured as follows.

1. Do you like the activities that have been carried out on the Desmos website? Please explain your reasons.
2. In your opinion, what mathematical topics or concepts are related to the activities on the Desmos website that you have done?
3. Would you like to learn mathematics using the Desmos website activities?

**Media Selection**. The media chosen is the Desmos Classroom web which can be used on a PC or Android without installing.

**Format Selection**. The format contained in digital simulations is the introduction, simulation, observation table, and three tasks.

**Media Design and Student Response**. The following is a display of creating a digital simulation in Figure 2 and Figure 3. Then a display of the digital simulation for students in Figure 4, Figure 5, and Figure 6 along with three tasks, namely in Figure 7, Figure 8, and Figure 9.

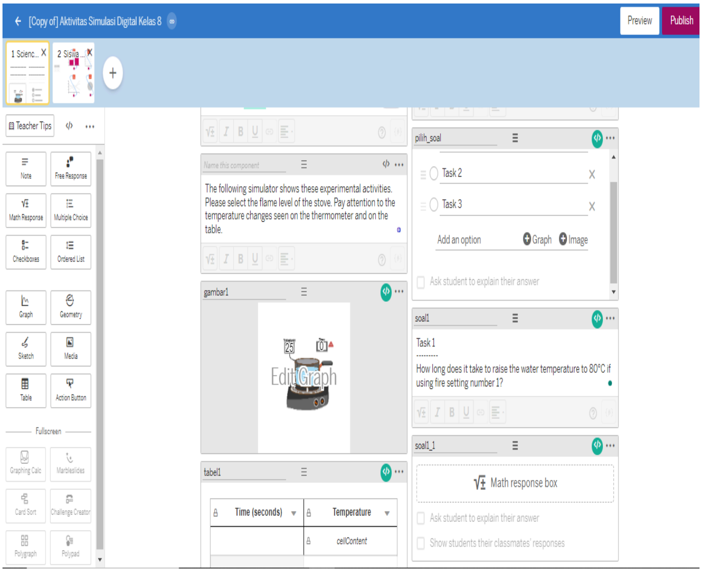



**Fig. 2.** Display of digital simulation creation

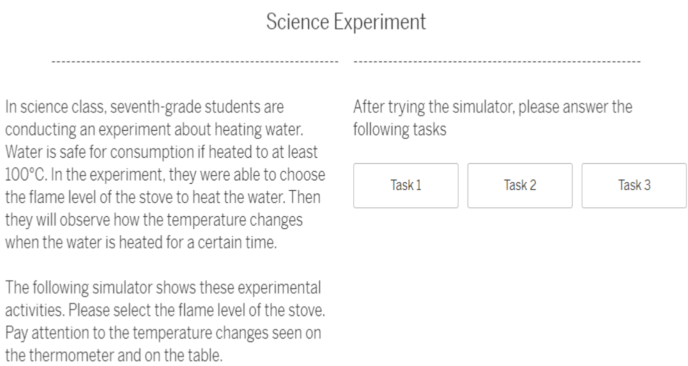
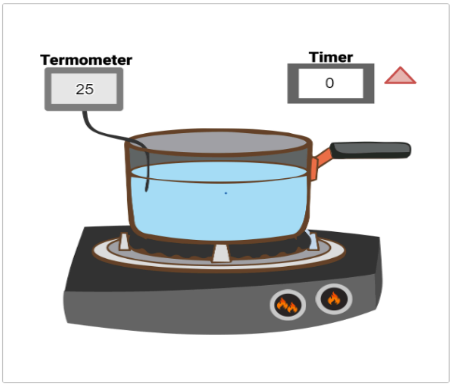



**Fig. 3.** Preliminary display of tasks




| Time (seconds) | Temperature |
|---|---|
| | 25 °C |

Write down the observation results in the following table

| Time (Seconds) | Temperature (°C) |
|---|---|
| | |
| | |
| | |
| | |
| | |

**Fig. 4.** Water heating simulation display and observation table

The following are the results of students' work on three digital simulation tasks.

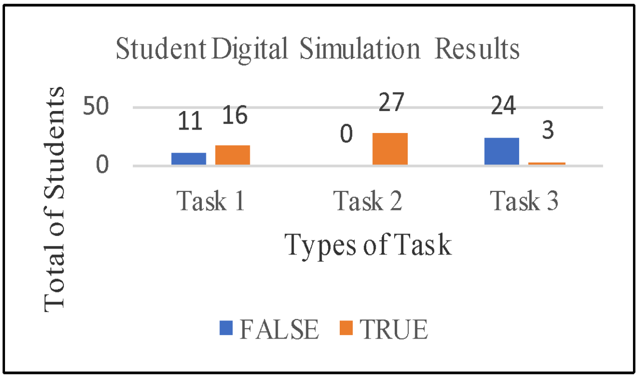


**Fig. 5.** Results of student digital simulation

Based on Figure 4, information was obtained that more students answered correctly on task 1 than incorrectly, for task number 2 all students answered correctly, and for task number 3 only three students answered correctly. The following is an explanation of students' answers for each task.

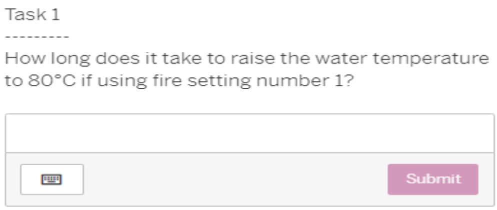



**Fig. 6.** Task 1

In task 1, students are asked to find the length of time needed to raise the water temperature to 80 $^{0}$C if using fire setting number 1. Task number 1 requires students' ability to process existing data. In task number 1, many students questioned the meaning of "fire setting number 1". It would be better if the number 1 fire setting is clarified as "small fire setting". The use of words in the question must be clear so that students do not guess the meaning of the question [25]. A total of sixteen students answered task 1 correctly, namely 436 seconds. Other students made mistakes because they were not careful in determining the time needed to reach a temperature closest to 80$^{0}$C. Apart from the ability to process data, a student's ability that also needs to be honed is accuracy. Students who are less careful when working on numeracy questions also occur in Kusmayadi, Sahara, and Fitriana's research [26]. Students need to get used to checking the procedures and results obtained again.

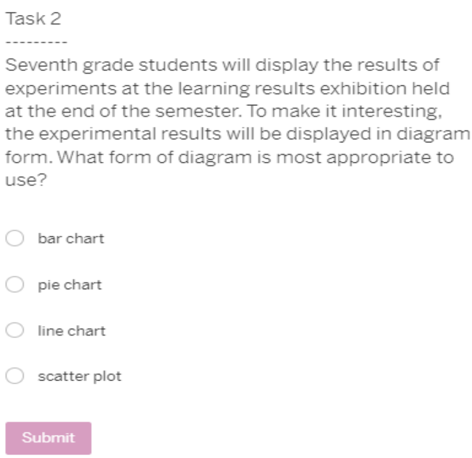



**Fig. 7.** Task 2

In task number 2, all students were able to answer correctly, namely a line diagram. Line diagrams are suitable for presenting experimental results because they present changes in temperature for each change in time. Students need to understand the form of data presentation that is appropriate to the data they have so that it is easy to interpret [27]. From that result, we know that that students can process data and understand appropriate diagrams for presenting data when using digital simulation. the statement is the same as Las Peñas et al's research that the use of digital simulations makes it easier for students to organize data [22].

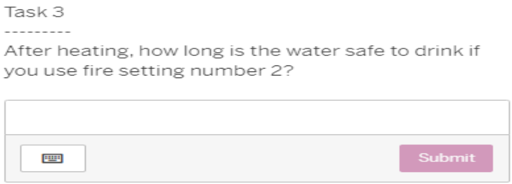



**Fig. 8.** Task 3

In task 3, which tested students' ability to process data, only three people answered correctly. This can happen because students misunderstand the meaning of the task. Students think the higher the temperature, the safer it is to drink. What is meant in the task is after heating how long does it take for the temperature to reach 100$^0$C (which is closest to 100$^0$C)? This task needs revision by clarifying the task. Student errors in number 3 are the same as number 1, namely in word choice. Transparent sentences give rise to many perceptions from students [25].

After students work on the simulation, students fill out a questionnaire. The following are the results of student questionnaire responses.

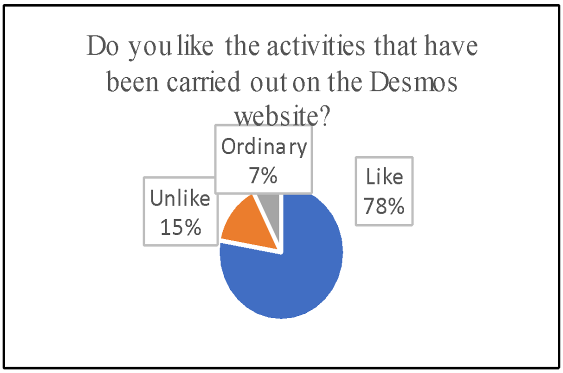



**Fig. 9.** Response to question 1

In Figure 9 the majority of students like learning that uses technology, for example, digital simulations. 21 students adored the digital simulation activity, two students did not adore it, and four students did not adore it. Those results are in line with Las

Peñas et al's research that the use of digital simulations can indeed increase students' motivation to study mathematics [22].

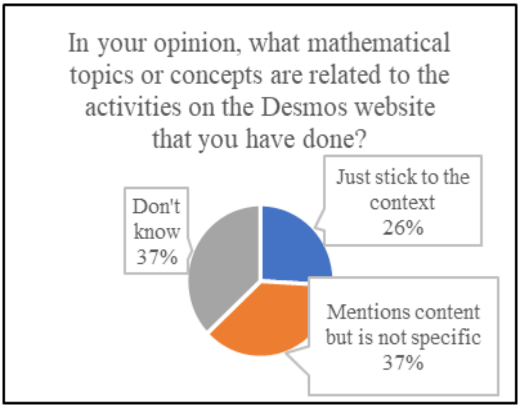



**Fig. 10.** Response to question 2

For task 2, students were unable to mention mathematical material that was appropriate to the task, namely the presentation of data they had studied in elementary school. Based on Wijaya et al., one of the students' difficulties is identifying the mathematical topic discussed in the problem [28]. Seven students mentioned the context of temperature and ten students mentioned the content of calculating temperature.

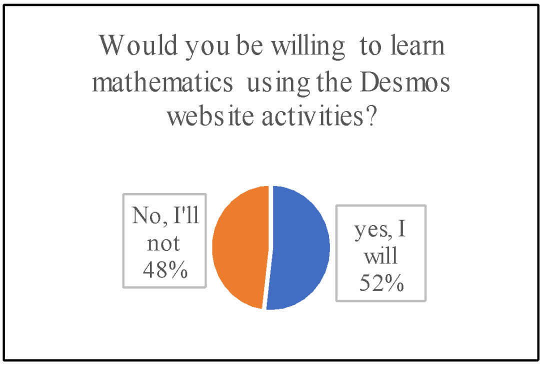



**Fig. 11.** Response to question 3

A total of fourteen students were willing to learn using the Desmos digital simulation while thirteen students were not willing. The problem that occurs are the network and its operation, which is a little complicated because it uses a smartphone. Stable network access and selection of appropriate devices such as PC are required to make it easier for students to use digital simulations. Bakhov et al state that those two things are the factors for the success of learning using technology [29]. Therefore, for future research it is better to provide a stable network and appropriate equipment for students.

This research has theoretical, practical and methodological benefits. The theoretical benefit of the research is that it can be used as a reference in developing digital numeracy simulations. Meanwhile, for practical benefits, it can be used by teachers to develop student numeracy and methodological benefits are overcoming the limitations of previous research.

## 4 Conclusion

This research aims to develop a digital simulation to improve junior high school students' numeracy skills. The digital simulation of uncertainty and data that has been developed can support junior high school students' numeracy skills based on responses to the three tasks and student questionnaire responses. Students need to be more careful in working on the questions and better understand the meaning of the questions. Product revision requires accuracy in choosing words in the questions, providing a stable network, and providing appropriate devices such as PCs or tablets. The limitation of this research is only using uncertainty and data content. Further research is needed at the development and dissemination stages.

## References

1. P. Liljedahl, "Numeracy task design: a case of changing mathematics teaching practice," *ZDM - Int. J. Math. Educ.*, vol. 47, no. 4, pp. 625–637, 2015, doi: 10.1007/s11858-015-0703-6.
2. OECD, *PISA 2022 Mathematics Framework*. 2018. [Online]. Available: https://pisa2022-maths.oecd.org/files/PISA 2022 Mathematics Framework Draft.pdf
3. Centre of Assessment and Learning (CAL), "AKM dan Implikasinya dalam Pembelajaran (Minimum Competency Assessment and its Implications for Learning)," 2020.
4. OECD, "PISA 2022 Results," 2022.
5. R. H. N. Sari and A. Wijaya, "Mathematical literacy of senior high school students in Yogyakarta," *J. Ris. Pendidik. Mat.*, vol. 4, no. 1, pp. 100–107, 2017, doi: 10.21831/jrpm.v4i1.10649.
6. F. K. Nisa and E. Arliani, "Junior high school students' mathematical literacy in terms of mathematical self-efficacy," *J. Elem.*, vol. 9, no. 1, pp. 283–297, 2023, doi: 10.29408/jel.v9i1.7140.
7. A. Wijaya, M. Van Den Heuvel-panhuizen, and M. Doorman, "Difficulties in solving context-based PISA mathematics tasks : An analysis of students ' errors," *Math. Enthus.*, vol. 11, no. 3, pp. 555–584, 2014.
8. Y. M. Sari and E. Valentino, "An Analysis of Students Error In Solving PISA 2012 And Its Scaffolding," *JRAMathEdu (Journal Res. Adv. Math. Educ.*, vol. 1, no. 2, pp. 90–98, 2017, doi: 10.23917/jramathedu.v1i2.3380.
9. Harpian, I. Rahma Suwarma, and A. Setiawan, "The Application of STEM Learning to Improve Students' STEM Literacy in The Knowledge Aspect," *J. Innov. Educ. Cult. Res.*, vol. 4, no. 3, pp. 450–457, 2023, doi: 10.46843/jiecr.v4i3.676.
10. H. Nugraha, "Improvement of Mathematical Literacy with Differentiation Learning Model," in *Proceedings of the 7th International Symposium on Mathematics Education and Innovation (ISMEI 2022)*, Atlantis Press International BV, 2023, pp. 103–113. doi: 10.2991/978-94-6463-220-0_12.

11. D. S. Nusantara, Zulkardi, and R. I. I. Putri, “Designing PISA-like mathematics problem in covid-19 pandemic (PISAComat),” *J. Phys. Conf. Ser.*, vol. 1657, no. 1, 2020, doi: 10.1088/1742-6596/1657/1/012057.
12. Zulkardi *et al.*, “Designing PISA-like task on uncertainty and data using Covid-19 context,” *J. Phys. Conf. Ser.*, vol. 10, no. 1, pp. 157–169, 2019, doi: 10.1088/1742-6596/1722/1/012102.
13. E. T. Aulia and R. C. I. Prahmana, “Developing interactive e-module based on realistic mathematics education approach and mathematical literacy ability,” *J. Elem.*, vol. 8, no. 1, pp. 231–249, 2022, doi: 10.29408/jel.v8i1.4569.
14. M. Purbaningrum, T. K. Nisa’, I. R. F. Febriani, and A. W. Kohar, “Flip-Stik for Flipped Classroom: Statistics Learning E-Module Assisted By Flipbook To Promote Students’ Numeracy,” *AKSIOMA J. Progr. Stud. Pendidik. Mat.*, vol. 11, no. 1, p. 276, 2022, doi: 10.24127/ajpm.v11i1.4428.
15. J. B. Bush, D. C. Webb, N. E. Kress, W. Yang, and K. K. Perkins, “Classroom Activities for Digital Interactive Simulations to Support Realistic Mathematics Education,” *6th Int. Realis. Math. Educ. Conf.*, pp. 1–31, 2018.
16. M. Kalogiannakis and S. Papadakis, “Combining mobile technologies in environmental education: a Greek case study,” *Int. J. Mob. Learn. Organ.*, vol. 11, no. 2, p. 108, 2017, doi: 10.1504/ijmlo.2017.10005249.
17. F. Haryani and Y. Y. Harso, “Promoting Mathematical Literacy Using Desmos Polygraph,” *Southeast Asia Math. Educ. J.*, vol. 13, no. 1, pp. 31–42, 2023.
18. N. N. S. P. Verawati, L. S. Handriani, and B. K. Prahani, “The Experimental Experience of Motion Kinematics in Biology Class Using PhET Virtual Simulation and Its Impact on Learning Outcomes,” *Int. J. Essent. Competencies Educ.*, vol. 1, no. 1, pp. 11–17, 2022, doi: 10.36312/ijece.v1i1.729.
19. Z. Tatli and A. Ayas, “Effect of a virtual chemistry laboratory on students’ achievement,” *J. Educ. Technol. Soc.*, vol. 16, no. 1, pp. 159–170, 2013.
20. C. T. Batuyong and A. Vida, “Exploring the Effect of PhET ® Interactive Simulation-Based Activities on Students’ Performance and Learning Experiences in Electromagnetism,” *Asia Pacific J. Multidiscip. Res.*, vol. 6, no. 2, pp. 121–131, 2018.
21. D. Vlachopoulos and A. Makri, *The effect of games and simulations on higher education: a systematic literature review*, vol. 14, no. 1. 2017. doi: 10.1186/s41239-017-0062-1.
22. M. L. A. N. D. Las Peñas, D. M. Verzosa, M. A. Q. Aberin, L. P. D. M. Garces, and F. F. Francisco, “Digital Simulations for Grade 7 to 10 Mathematics Digital Simulations for Grade 7 to 10 Mathematics Recommended Citation Recommended Citation,” *Philipp. J. Sci.*, vol. 148, no. 4, pp. 735–749, 2019.
23. S. Thiagarajan, *Instructional development for training teachers of exceptional children: A source book*. University of Minnesota, 1974.
24. J. W. Creswell, *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*, 4th editio. 4th editio.housand Oaks, CA: Sage, 2014.
25. I. L. Beck, M. G. McKeown, and L. Kucan, *Bringing words to life: Robust vocabulary instruction*. Guilford Press, 2013.
26. T. A. Kusmayadi, S. Sahara, and L. Fitriana, “Application of Newman Errors Analysis theory related to mathematical literacy problems: A case study of secondary students in class 11,” in *AIP Conference Proceedings*, 2022. doi: https://doi.org/10.1063/5.0117183.
27. T. L. Weissgerber, N. M. Milic, S. J. Winham, and V. D. Garovic, “Beyond Bar and Line Graphs: Time for a New Data Presentation Paradigm,” *PLoS Biol.*, vol. 13, no. 4, pp. 1–10, 2015, doi: 10.1371/journal.pbio.1002128.

28. A. Wijaya and M. Van Den Heuvel-panhuizen, "Opportunity-to-learn context-based tasks provided by mathematics textbooks," *Educ. Stud. Math.*, no. 89, pp. 41–65, 2015, doi: 10.1007/s10649-015-9595-1.
29. I. Bakhov, N. Opolska, M. Bogus, V. Anishchenko, and Y. Biryukova, "Emergency distance education in the conditions of COVID-19 pandemic: Experience of Ukrainian universities," *Educ. Sci.*, vol. 11, no. 7, 2021, doi: 10.3390/educsci11070364.