



Supporting Proportional Reasoning Through Technology Integration in Mathematics Learning

Ahmad Lutfi, Nurjanah, Bambang Avip Priatna Martadiputra*, Al Jupri
Mathematics Education Department, Faculty of Mathematics and Science Education,
Universitas Pendidikan Indonesia.

*Corresponding Author. Email: bambangavip@upi.edu

Abstract: This study aims to analyze the role of technology in facilitating the development of students' proportional reasoning skills in mathematics learning. This study used the systematic literature review method with a qualitative approach. Documents on the Scopus database were analyzed according to the research objectives using the PRISMA 2020. Thematic analysis was applied to all documents included in the search results. The results of this study indicated that there were 18 documents found that addressed the chosen topic-first in 2006, with 2015 being the most productive year discussing this topic. The technologies used to facilitate the development of proportional reasoning skills are Flash/ActionScript 3 programs-dominated, robotics, web-based learning, interactive touchscreen tablet application (MIT-Ext)-ordered by document quantity, virtual reality (VR), GeoGebra, video games, and augmented reality (AR). Quantitative, qualitative, and mixed-method approaches were used in almost equal parts. Junior high school was the most researched level of this topic, but no research has been conducted at the senior high school level. The most productive country to research this topic was the Netherlands. The results of this study were expected to provide practical benefits for teachers and future research.

Article History

Received: 19-12-2023
Revised: 28-01-2024
Accepted: 10-02-2024
Published: 09-03-2024

Key Words:

Proportional Reasoning;
Technology; Mathematics
Learning.

How to Cite: Lutfi, A., Nurjanah, N., Martadiputra, B., & Jupri, A. (2024). Supporting Proportional Reasoning Through Technology Integration in Mathematics Learning. *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran*, 10(1), 136-146. doi:<https://doi.org/10.33394/jk.v10i1.10166>



<https://doi.org/10.33394/jk.v10i1.10166>

This is an open-access article under the [CC-BY-SA License](#).



Introduction

Mathematics learning equips students with various important abilities (Nopriana et al., 2021), which can include understanding skills, reasoning skills, problem solving skills, communication skills, connection skills, critical thinking skills, and creative thinking skills. Good mastery of mathematics plays an important role in academic, economic and general life success (Rittle-Johnson et al., 2019). For example, in decision making, students with good mathematical skills will be wiser in determining a decision. Students with good reasoning skills can lead students to better understand and apply mathematical concepts in everyday (Marasabessy, 2021). Mathematical reasoning is the ability to use logic and critical thinking to analyze and justify mathematical statements, arguments and proofs. Mathematical reasoning involves using mathematical facts, definitions, rules, and principles to construct valid arguments and draw valid conclusions. Therefore, reasoning is so important that teachers make reasoning one of the focuses in teaching mathematics (Mujib & Sulistiana, 2023).

Proportional reasoning is one of the fundamental ones. This skill is learnt from primary grade to tertiary level, so proportional reasoning skills must be well mastered by students in order to succeed in the next level of mathematics (Wynkoop, 2022). Proportional reasoning is concerned with the core of introducing students to the understanding of ratio (Tjoe & Torre, 2014). Proportional reasoning skills have practical functions in classroom



mathematics learning, other subjects, and everyday life (Ayuningtyas, 2019). Some mathematics materials require proportional reasoning, such as ratio, comparison, geometry, congruence, and measurement in elementary and junior high school, and also trigonometry and probability in senior high school.

Increasing digitalization is characterized by the integrated use of technology in various daily activities. The use of technology has now influenced various aspects of life (Agyei et al., 2023). The influence of technology can include how to communicate, work, learn, and other daily life activities. Lack of knowledge about technological developments will affect one's performance at work (Ryd et al., 2018). The deepening role of technology in various fields makes technology an important element in bridging daily life towards progress and transformation that continues to grow. The presence of technological developments also increases participation in daily life activities (Ramsten et al., 2020). The usefulness of technology can be expressed in the form of instruments that make things easier, technical advances, and improvement tools (Dağhan, 2017). This development should certainly trigger the optimal utilization of technology in improving the quality of life in general.

Technological developments in education should be seen as a way to improve the quality of education (Fredlina et al., 2021), because education is one of the effective ways to improve the quality or progress of a nation (Rianto et al., 2020). The utilization of technology in the field of education can broadly include information system management, e-learning, and learning media (Husaini, 2014). The development of technology has offered an interesting integration in learning practices. Learning by utilizing technology has been shown to improve cognitive, metacognitive, and affective abilities (Pierce et al., 2007). In addition, learning with technology can also make learning more efficient, and can provide faster feedback to students (Gunawan et al., 2023), interesting, interactive, and relevant according to the times. The use of technology that has a significant impact on teaching and learning outcomes leads to surging technology investments globally (Agyei et al., 2023).

The presence of technology is a new and promising potential in the rapid transformation of mathematics teaching and learning (Lavicza, 2010). The integration of technology in improving mathematics teaching and learning outcomes has been advocated by various groups (Drijvers, 2015), ranging from mathematics teachers, curriculum developers, and mathematics education researchers (Agyei et al., 2022). The role of effective use of technology is to (a) encourage the proof cycle, (b) present and connect various representations, (c) support case-based reasoning, and (d) act as a tutee. It shows that teachers must be able to master the use of technology to support mathematics learning. The use of technology in learning mathematics has been shown to improve learning achievement and positive student attitudes (Eyyam & Yaratan, 2014). Even better, the use of technology has a significant overall impact on student achievement, motivation and attitudes (Higgins et al., 2019).

In practice, several factors determine the success of integrating technology in mathematics education: design, teacher role and educational context (Drijvers, 2015). Thus, in teacher education programmes it is important to focus on the type of tools, how teachers position them in mathematics learning, and how certain activities are carried out in accordance with mathematics learning objectives (McCulloch et al., 2018). Classroom learning practices have been influenced by the use of technology in a positive direction. An example is the use of electronic textbooks as a technology used daily in the classroom (Chiu, 2017). The textbooks referred to here are not just paper textbooks in electronic format, but textbooks that allow for collaborative, interactive and other authentic activities.



Some documents examine that research in recent years on proportional reasoning focuses on cognitive paradigms and on student difficulties in describing proportional reasoning (Wijayanti & Winslow, 2017), and some examine systematic literature reviews in developing students' proportional reasoning skills in mathematics learning environments have not focused on technology integration (Lutfi et al., 2023). Systematic literature review research conducted by Susanto et al., (2023) which examines the use of technology in improving students' mathematical problem skills, the results show that the GeoGebra application is the technology most often used in developing students' mathematical understanding skills. In addition, research conducted by Sunzuma (2023) examines the integration of technology in teaching and learning geometry, the results show that GeoGebra is the most frequently used application in teaching and learning geometry materials integrated with technology.

From various literature that discusses the use of technology in mathematics learning, there needs to be a systematic literature review that focuses on the use of technology to facilitate the development of students' proportional reasoning skills. It will benefit teachers because, in fact, the level of competence in technology integration is an important factor and has an influence on the practices carried out by teachers to achieve better results in student development (Al-Abdullatif & Alsaed, 2019), besides that the systematic literature review can also explore data on how much research has been done by researchers on the topic that has been determined. This study aims to analyze the role of technology in facilitating the development of students' proportional reasoning skills in mathematics learning. It will be useful for teachers in implementing learning in the mathematics classroom.

Research Method

This study used the systematic literature review method with a qualitative approach. The systematic literature review method emphasized classifying, selecting, assessing, or counting critically significant investigations and collecting and examining information from the findings for review (Aliyu et al., 2021). Researchers used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to screen documents that fit the topic of systematic literature review (Moher et al., 2015; Page et al., 2021), which consists of four stages, namely identification, screening, eligibility, and inclusion (Selçuk, 2019). The search results on the Scopus database with a search based on "Article title, abstract, and keyword" using the keywords "mathematics" AND "proportional reasoning" (Haddaway et al., 2022).

To determine the documents included in this study, researchers used inclusion criteria, which is useful for recommending authors to cite documents on the topic and explaining why studies are excluded (Page et al., 2021). The inclusion criteria in this systematic literature review are as follows: 1) Documents that discuss the use of technology to develop students' proportional reasoning skills that can be sourced from articles, book chapters, and conference papers, for review documents, editorials, letters, and notes are excluded; 2) all documents included in the search results and indexed by Scopus are included in the document selection; and 3) researchers chose to review all documents from the beginning of the search results year until the date the search was conducted, namely 12 December 2023, even though the first year the appropriate document was found was in 2006. The data analysis technique used in this research was thematic analysis.

Results and Discussion

Based on the search results on the Scopus database, 206 documents were found, and 18 documents met the inclusion criteria. The results of the systematic literature review are

presented in the form of: 1) the trend of article publication from year to year; 2) the technology used; 3) the research methods used; 4) the level of research subjects or samples; and 5) the location of the research. This systematic literature review analyzed 18 documents sourced from 12 articles, 2 book chapter documents, and 4 conference paper documents. The results of the analysis are presented as follows:

Study based on year publication

The results of the systematic literature review obtained 18 documents that focus on the use of technology to develop proportional reasoning skills in mathematics learning. All documents reviewed from the Scopus database obtained documents that discuss this matter starting in 2006. The following document publication trend is presented in Figure 1.

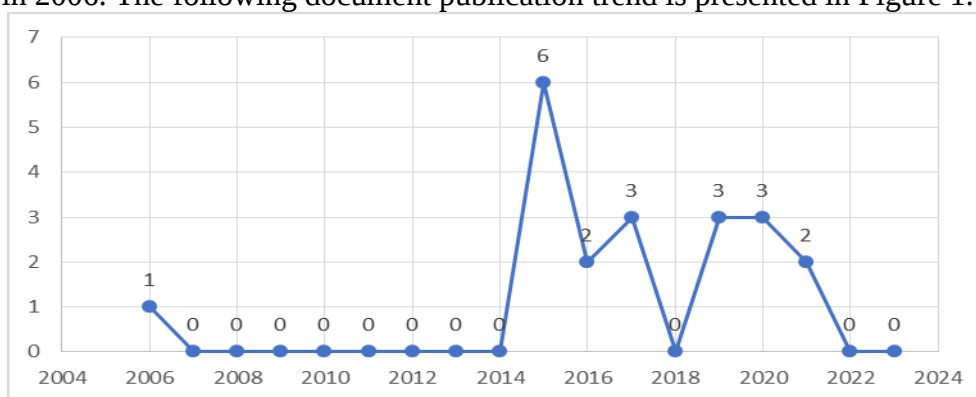


Figure 1. Study based on year of publication

Based on Figure 1, the publication of scientific documents that discuss the use of technology in developing students' proportional reasoning skills in mathematics learning was found starting in 2006 written by Norton (2006). However, from 2007 to 2014, no related publications were found and began to exist again in 2015, which directly contained 6 documents with the most publications. However, it has decreased again; even in 2018, 2022, and 2023, no related publications have been found. This shows that research on the use of technology in facilitating students' proportional reasoning skills in mathematics learning has received sufficient attention by several researchers, although the trend still shows ups and downs.

Study based on technology used

Various types of technology have been used to facilitate the development of students' proportional reasoning skills. The majority of researchers used the "Zeldenrust" tool with a total of 6 documents (Vrugte et al., 2015, 2017; Wouters, Oostendorp, Vrugte, Jong, et al., 2015; Wouters, Oostendorp, Vrugte, Vandercruysse, et al., 2015; Wouters et al., 2016, 2017). Zeldenrust is a 2D game tool developed by utilising the Flash/ActionScript 3 program, which is a popular medium for developing interactive media (Paat et al., 2019). The Zeldenrust application is provided by the researcher at the link <http://www.projects.science.uu.nl/mathgame/zeldenrust/index.html>. The game presents activities that cover certain types of problems in the domain of proportional reasoning (Wouters et al., 2016). Robotics is also used to facilitate students in developing proportional reasoning, there are 5 documents that discuss it (Alfieri et al., 2015; Cheng et al., 2021; Kessler et al., 2020; Norton, 2006; Ortiz, 2015), two of which utilise LEGO Robotic (Norton, 2006; Ortiz, 2015). LEGO Robotics is the result of a collaboration between Massachusetts Institute of Technology (MIT) researchers and the LEGO® Company to design a unit equipped with computational capabilities that can accommodate the installation of traditional LEGO blocks that can be controlled (Ortiz, 2015), the results showed that students'

proportional reasoning improved. Another document that utilised robotics was written by Alfieri et al. (2015), he used a 3D game called "Expedition Atlantis". The next document has one research each, namely by utilising Dynabook which is a device in facilitating web-based learning (Courey et al., 2015), Scalebridge by utilising virtual reality (VR) (Pietroszek & Tahai, 2019), GeoGebra (Faria & Maltempi, 2019), video games (Wisittanawat & Gresalfi, 2020), and augmented reality (AR) (Arican & Özçakir, 2021).

Study based on research approach

Research on the utilisation of technology in facilitating the development of students' proportional reasoning skills uses different approaches are presented in Figure 2 below.

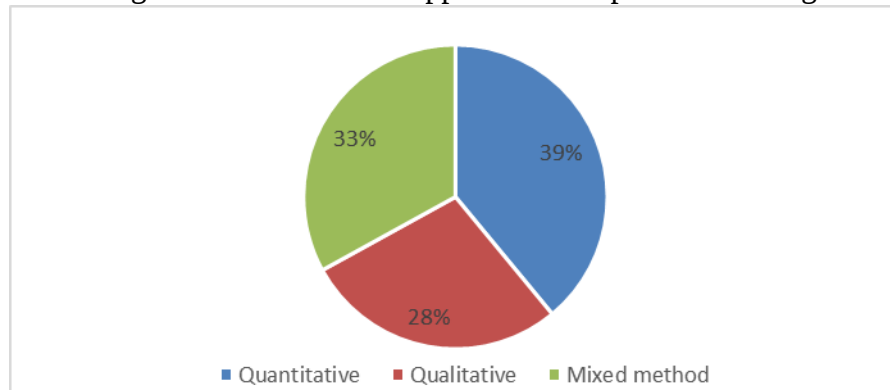


Figure 2. Study based on research approach

Based on Figure 2, quantitative approach was used in 7 documents (39%), qualitative approach was used in 5 documents (28%), and mixed-method was used in 6 documents (33%). The quantitative approach was used in the research of Cheng et al. (2021); Vrugte et al. (2015, 2017); Wouters et al. (2016, 2017); Wouters, Oostendorp, Vrugte, Jong, et al. (2015); dan Wouters, Oostendorp, Vrugte, Vandercruysse, et al. (2015). Qualitative approaches were carried out in the research of Arican & Özçakir (2021); Faria & Maltempi (2019); Pietroszek & Tahai (2019); Shayan et al. (2016); and Wisittanawat & Gresalfi (2020). Mixed method was conducted in the research of Alfieri et al. (2015); Courey et al. (2015); Duijzer et al. (2017); Kessler et al. (2020) dan Norton (2006); dan Ortiz, 2015). The Research and Development type has not been used on the topic of technology utilisation to facilitate the development of students' proportional reasoning, even though this type of research can also be used in the field of education.

Study based on educational level

The next discussion is based on the education level of the research. The utilisation of technology in facilitating the development of proportional reasoning skills based on education level is presented in Figure 3.

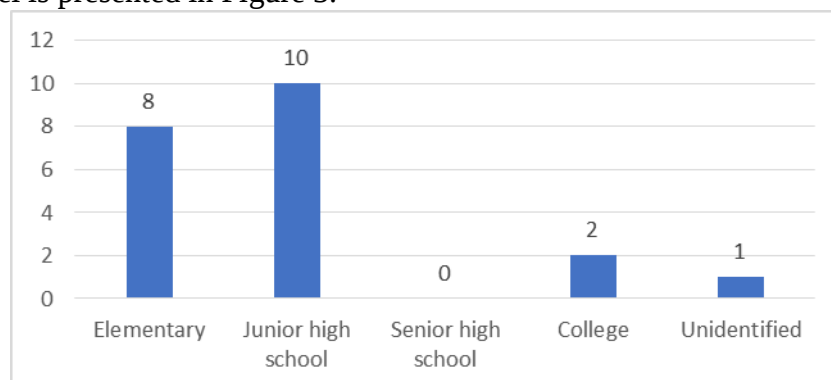


Figure 3. Study based on educational level

Based on Figure 3, the majority of research on the use of technology in facilitating the development of proportional reasoning was conducted at the junior high school level. This is supported by the fact that proportional reasoning is widely studied at the junior high school level (Dağhan, 2017), is critical in mathematics success, and is a determinant of success outside of school. However, based on a systematic literature review, no research has been conducted at the senior high school level, even in other subjects (Suryadi et al., 2020). In fact, at the high school level, proportional reasoning is also quite widely studied, so in the future, other studies can be carried out.

Study based on research location

The last discussion of systematic literature is based on the location of the research presented in Figure 4.

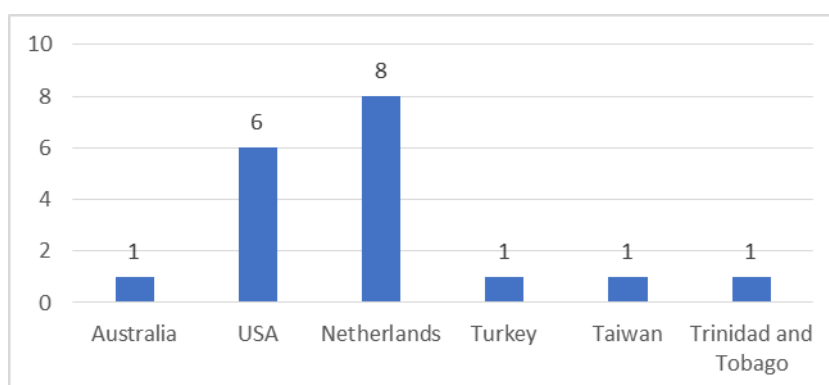


Figure 4. Study based on research location

Based on Figure 4, research on the utilisation of technology to facilitate the development of proportional reasoning skills is mostly conducted in the Netherlands, namely 8 studies. In the USA, 6 studies were conducted. Australia, Turkey, Taiwan and Trinidad and Tobago each conducted 1 study. This shows that the Netherlands makes good use of technology to facilitate the development of students' proportional reasoning skills in mathematics learning. This is supported by the research of Drijvers et al. (2021), which states that at the time of Covid-19 requiring schools to close, the Netherlands became a country with the highest level of intensity in the use of technology among the countries of Flanders, and Germany.

The results of this systematic literature review show that technology plays an important role in facilitating the development of students' proportional reasoning skills. Teachers can utilize various technologies to facilitate the development of proportional reasoning skills. Some technologies that can be used are Flash/ActionScript 3 program, robotic, web-based learning, virtual reality (VR), GeoGebra, video games, and augmented reality (AR). The choice of technology used can be adjusted to the preferences of teachers, students, and school resources because, of course, not all elements have the same access. The learning syntax used by teachers can also refer to the documents included in this systematic literature review.

Conclusion

Based on the results of the systematic literature review, the results show that 2006 was the first year that documents were found that discussed the utilization of technology to facilitate the development of students' proportional reasoning skills. 2015 was the most productive year that discussed the utilization of technology to facilitate the development of students' proportional reasoning skills. The most widely used technology to facilitate the development of students' proportional reasoning skills is "Zeldenrust" which utilizes Flash/ActionScript 3

programs; other technologies are robotics, web-based learning, interactive touchscreen tablet application (MIT-Ext), Scalebridge by utilizing virtual reality (VR), GeoGebra, video games, and augmented reality (AR). The research approaches used are almost balanced between quantitative approaches, qualitative approaches, and mixed methods. Research related to the topic is mostly conducted at the junior high school level, but topical research has not facilitated high school students. The location of the research was mostly conducted in the Netherlands.

Recommendation

Some recommendations that researchers can give are for educators or mathematics teachers to use some of the references presented as suggestions for improving students' proportional reasoning with the integration of technology in mathematics learning. Future research can also conduct similar research to see more deeply how the use of technology facilitates the development of students' proportional reasoning. From the review that has been done, no research has been found that facilitates students in high school so that future research can be carried out at the high school level. Research that focuses on research and development (R&D) can also be conducted.

Acknowledgment

The authors would like to thank LPDP (Lembaga Pengelola Dana Pendidikan), which is part of the Ministry of Finance of the Republic of Indonesia for assisting the authors in financing the master's program and writing this article to be published. The author would also like to thank Prof. Dr. Nurjanah, M.Pd., Dr. Bambang Avip Priatna Martadiputra, M.Pd., and Prof. Al Jupri M.Sc., Ph.D who has guided patiently, provided constructive suggestions in the preparation of this article.

References

- Agyei, E., Agyei, D. D., & Benning, I. (2023). Teaching mathematics with digital technologies: A situational analysis of high school teachers' experiences in Ghana. *African Journal of Research in Mathematics, Science and Technology Education*, 0(0), 1–14. <https://doi.org/10.1080/18117295.2023.2265241>
- Agyei, E., Darko Agyei, D., & Benning, I. (2022). In-service mathematics teachers' preparedness, knowledge, skills, and self-efficacy beliefs of using technology in lesson delivery. *Cogent Education*, 9(1), 1–21. <https://doi.org/10.1080/2331186X.2022.2135851>
- Al-Abdullatif, A. M., & Alsaeed, M. S. (2019). Evaluating visible learning: Mathematics teachers' practices in technology-enhanced classrooms. *Cogent Education*, 6(1). <https://doi.org/10.1080/2331186X.2019.1686798>
- Alfieri, L., Higashi, R., Shoop, R., & Schunn, C. D. (2015). Case studies of a robot-based game to shape interests and hone proportional reasoning skills. *International Journal of STEM Education*, 2(1). <https://doi.org/10.1186/s40594-015-0017-9>
- Aliyu, J., Osman, S., Daud, M. F., & Kumar, J. A. (2021). Mathematics teachers' pedagogy through technology: A systematic literature review. *International Journal of Learning, Teaching and Educational Research*, 20(1), 323–341. <https://doi.org/10.26803/IJLTER.20.1.18>
- Arican, M., & Özçakir, B. (2021). Facilitating the development of preservice teachers' proportional reasoning in geometric similarity problems using augmented reality activities. *Education and Information Technologies*. <https://doi.org/10.1007/s10639->

020-10359-1

- Ayuningtyas, G. F. (2019). *Peningkatan kemampuan penalaran proporsional dan pencapaian self-regulated learning siswa sekolah menengah pertama melalui problem-based learning ditinjau dari gaya kognitif* [Universitas Pendidikan Indonesia]. <http://repository.upi.edu/40187/>
- Cheng, P. J., Liao, Y. H., & Yu, P. T. (2021). Micro:bit robotics course: infusing logical reasoning and problem-solving ability in fifth grade students through an online group study system. *International Review of Research in Open and Distance Learning*, 22(1), 21–40. <https://doi.org/10.19173/irrodl.v22i1.4844>
- Chiu, T. K. F. (2017). Introducing electronic textbooks as daily-use technology in schools: A top-down adoption process. *British Journal of Educational Technology*, 48(2), 524–537. <https://doi.org/10.1111/bjet.12432>
- Courey, S., LePage, P., Blackorby, J., Siker, J., & Nguyen, T. (2015). The effects of using dynabook to prepare special education teachers to teach proportional reasoning. *International Journal of Web-Based Learning and Teaching Technologies*, 10(1), 45–64. <https://doi.org/10.4018/ijwltt.2015010104>
- Dağhan, G. (2017). Views of students about technology, effects of technology on daily living and their professional preferences. *Turkish Online Journal of Educational Technology*, 16(4), 187–194. <https://eric.ed.gov/?id=EJ1160606>
- Drijvers, P. (2015). Digital technology in mathematics education: Why it works (or doesn't). *Selected Regular Lectures from the 12th International Congress on Mathematical Education*, 135–151. <https://doi.org/10.1007/978-3-319-17187-6>
- Drijvers, P., Thurm, D., Vandervieren, E., Klinger, M., Moons, F., van der Ree, H., Mol, A., Barzel, B., & Doorman, M. (2021). Distance mathematics teaching in Flanders, Germany, and the Netherlands during COVID-19 lockdown. *Educational Studies in Mathematics*, 108(1–2), 35–64. <https://doi.org/10.1007/s10649-021-10094-5>
- Duijzer, C. A. C. G., Shayan, S., Bakker, A., Van der Schaaf, M. F., & Abrahamson, D. (2017). Touchscreen tablets: Coordinating action and perception for mathematical cognition. *Frontiers in Psychology*, 8(FEB), 1–19. <https://doi.org/10.3389/fpsyg.2017.00144>
- Eyyam, R., & Yaratana, H. S. (2014). Impact of use of technology in mathematics lessons on student achievement and attitudes. *Social Behavior and Personality: An International Journal*, 42(1), 31S–42S.
- Faria, R. W. S. de C., & Maltempi, M. V. (2019). Mathematical intradisciplinarity with GeoGebra in school mathematics. *Bolema: Boletim de Educação Matemática*, 33(63), 348–367. <https://doi.org/10.1590/1980-4415v33n63a17>
- Fredlina, K. Q., Putri, G. A. M., & Astawa, N. L. P. N. (2021). Penggunaan teknologi sebagai media pembelajaran matematika di era new normal. *Jurnal Karya Abdi Masyarakat*, 5(1), 1–6. <https://doi.org/https://doi.org/10.22437/jkam.v5i1.13808>
- Gunawan, R. G., Festiyed, F., Yermadesi, Y., Ilwandri, I., & Gunawan, R. G. (2023). The problem-based learning model integrated with the integrated learning model in science learning: A systematic literature review. *Indonesian Journal of Science and Mathematics Education*, 6(2), 227–237. <https://doi.org/10.24042/ijms.v6i2.17576>
- Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. *Campbell Systematic Reviews*, 18(2), e1230. <https://doi.org/https://doi.org/10.1002/cl2.1230>
- Higgins, K., Huscroft-D'Angelo, J., & Crawford, L. (2019). Effects of technology in

- mathematics on achievement, motivation, and attitude: a meta-analysis. *Journal of Educational Computing Research*, 57(2), 283–319. <https://doi.org/10.1177/0735633117748416>
- Husaini, M. (2014). Pemanfaatan teknologi informasi dalam pendidikan. *Jurnal Mikrotik*, 2(1), 7–14. <https://doi.org/10.59134/jlmt.v5i1.311>
- Kessler, A., Boston, M., & Stein, M. K. (2020). Exploring how teachers support students' mathematical learning in computer-directed learning environments. *Information and Learning Science*, 121(1–2), 52–78. <https://doi.org/10.1108/ILS-07-2019-0075>
- Lavicza, Z. (2010). Integrating technology into mathematics teaching at the university level. *ZDM - International Journal on Mathematics Education*, 42(1), 105–119. <https://doi.org/10.1007/s11858-009-0225-1>
- Lutfi, A., Juandi, D., Avip, B., Martadiputra, P., Pendidikan Matematika, M., Matematika, F. P., Alam, I. P., & Pendidikan Indonesia, U. (2023). Development proportional reasoning in mathematics learning environment: Systematic literature review. *Pedagogy*, 8(1), 107–122. <https://doi.org/https://doi.org/10.30605/pedagogy.v8i1.2469>
- Marasabessy, R. (2021). Study of mathematical reasoning ability for mathematics learning in schools: A literature review. *Indonesian Journal of Teaching in Science*, 1(August), 79–90. <https://doi.org/10.17509/xxxx.xxxx>
- McCulloch, A. W., Hollebrands, K., Lee, H., Harrison, T., & Mutlu, A. (2018). Factors that influence secondary mathematics teachers' integration of technology in mathematics lessons. *Computers and Education*, 123(April), 26–40. <https://doi.org/10.1016/j.compedu.2018.04.008>
- Moher, D., Shamseer, L., Clarke, M., Gherzi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L. A., & Group, P.-P. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Japanese Pharmacology and Therapeutics*, 4(1), 1–9. <https://doi.org/10.1186/2046-4053-4-1>
- Mujib, A., & Sulistiana, E. (2023). Kemampuan penalaran proporsional menurut Langrall dan Swafford pada siswa Sekolah Menengah Pertama. *Plusminus: Jurnal Pendidikan Matematika*, 3(1), 117–126. <https://doi.org/10.31980/plusminus.v3i1.2577>
- Nopriana, T., Firmasari, S., & Martadiputra, B. A. P. (2021). Profile of hard skills and soft skills of mathematics education students. *Eduma : Mathematics Education Learning and Teaching*, 10(1), 1–13. <https://doi.org/10.24235/eduma.v10i1.6460>
- Norton, S. (2006). Pedagogies for the engagement of girls in the learning of proportional reasoning through technology practice. *Mathematics Education Research Journal*, 18(3), 69–99. <https://doi.org/10.1007/BF03217443>
- Ortiz, A. M. (2015). Examining students' proportional reasoning strategy levels as evidence of the impact of an integrated LEGO robotics and mathematics learning experience. *Journal of Technology Education*, 26(2), 46–69.
- Paat, M., Sutopo, H., & Siregar, N. (2019). Developing a mobile multimedia-based learning resource on living of komodo dragons. *ACM International Conference Proceeding Series*, 273–277. <https://doi.org/10.1145/3374587.3374592>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International Journal of Surgery*, 88(March). <https://doi.org/10.1016/j.ijsu.2021.105906>



- Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers and Education*, 48(2), 285–300. <https://doi.org/10.1016/j.compedu.2005.01.006>
- Pietroszek, K., & Tahai, L. (2019). Scalebridge VR: Immersive proportional reasoning game for children with brain-computer interface for difficulty scaling. *Proceedings of the 25th ACM Symposium on ...*. <https://doi.org/10.1145/3359996.3364734>
- Ramsten, C., Martin, L., Dag, M., & Hammar, L. M. (2020). Information and communication technology use in daily life among young adults with mild-to-moderate intellectual disability. *Journal of Intellectual Disabilities*, 24(3), 289–308. <https://doi.org/10.1177/1744629518784351>
- Rianto, B., Lutfi, A., Naser, A. D. M., & Dasari, D. (2020). The effect of prior knowledge and learning motivation on mathematics learning outcomes of junior high school students. *Jurnal Pendidikan*, 23(November), 1876–1886. <https://doi.org/http://dx.doi.org/10.23960/jpmipa/v23i4.pp1876-1886>
- Rittle-Johnson, B., Zippert, E. L., & Boice, K. L. (2019). The roles of patterning and spatial skills in early mathematics development. *Early Childhood Research Quarterly*, 46, 166–178. <https://doi.org/10.1016/j.ecresq.2018.03.006>
- Ryd, C., Malinowsky, C., Öhman, A., Kottorp, A., & Nygård, L. (2018). Older adults' experiences of daily life occupations as everyday technology changes. *British Journal of Occupational Therapy*, 81(10), 601–608. <https://doi.org/10.1177/0308022618774525>
- Selçuk, A. A. (2019). A Guide for Systematic Reviews: PRISMA. *Turkish Archives of Otorhinolaryngology*, 57(1), 57–58. <https://doi.org/10.5152/tao.2019.4058>
- Shayan, S., Abrahamson, D., Bakker, A., Duijzer, C. A. C. G., & Van Der Schaaf, M. (2016). Eye-tracking the emergence of attentional anchors in a mathematics learning tablet activity. In *Eye-Tracking Technology Applications in Educational Research* (Issue June 2017, pp. 166–194). <https://doi.org/10.4018/978-1-5225-1005-5.ch009>
- Sunzuma, G. (2023). Technology integration in geometry teaching and learning: A systematic review (2010-2022). *Lumat*, 11(3). <https://doi.org/10.31129/LUMAT.11.3.1938>
- Suryadi, A., Yulianti, L., & Wisodo, H. (2020). Could STEM-based phenomenon learning improve students' proportional reasoning. *ILHSS-20*, 26–31. <https://doi.org/https://doi.org/10.17758/DIRPUB8.DIR0320440>
- Susanto, A., Setyaningrum, W., Camellia, F., & Asriani, N. W. (2023). Tren pemanfaatan teknologi dalam meningkatkan kemampuan pemecahan masalah matematis siswa. *Aksioma*, 12(3), 3088–3100. <https://doi.org/https://doi.org/10.24127/ajpm.v12i3.7545>
- Tjoe, H., & Torre, J. de la. (2014). On recognizing proportionality: Does the ability to solve missing value proportional problems presuppose the conception of proportional reasoning? *Journal of Mathematical Behavior*, 33(1), 1–7. <https://doi.org/10.1016/j.jmathb.2013.09.002>
- Vrugte, J. ter, Jong, T. de, Vandercruysse, S., Wouters, P., Oostendorp, H. van, & Elen, J. (2015). How competition and heterogeneous collaboration interact in prevocational game-based mathematics education. *Computers and Education*, 89, 42–52. <https://doi.org/10.1016/j.compedu.2015.08.010>
- Vrugte, J. ter, Jong, T. de, Vandercruysse, S., Wouters, P., Oostendorp, H. van, & Elen, J. (2017). Computer game-based mathematics education: Embedded faded worked examples facilitate knowledge acquisition. *Learning and Instruction*, 50, 44–53. <https://doi.org/10.1016/j.learninstruc.2016.11.007>
- Wijayanti, D., & Winslow, C. (2017). Mathematical practice in textbooks analysis:



- Praxeological reference models, the case of proportion. *Journal of Research in Mathematics Education*, 6(3), 307–330. <https://doi.org/10.17583/redimat.2017.2078>
- Wisittanawat, P., & Gresalfi, M. S. (2020). Street mathematics and school mathematics in a video game. *Computer-Supported Collaborative Learning Conference, CSCL*, 1, 310–316.
- Wouters, P., Oostendorp, H. van, Vrugte, J. ter, Jong, T. de, VanderCruysse, S., & Elen, J. (2015). The role of surprising events in a math-game on proportional reasoning. *Proceedings of the European Conference on Games-Based Learning, 2015-Janua*, 613–620.
- Wouters, P., Oostendorp, H. van, Vrugte, J. ter, Vandercruysse, S., Jong, T. de, & Elen, J. (2015). The role of curiosity-triggering events in game-based learning for mathematics. In *Describing and Studying Domain-Specific Serious Games* (pp. 1–250). <https://doi.org/10.1007/978-3-319-20276-1>
- Wouters, P., Oostendorp, H. van, Vrugte, J. ter, VanderCruysse, S., Jong, T. de, & Elen, J. (2016). The role of surprise in game-based learning for mathematics. *Lecture Notes in Computer Science*, 9599, V–VI. <https://doi.org/10.1007/978-3-319-40216-1>
- Wouters, P., van Oostendorp, H., ter Vrugte, J., vanderCruysse, S., de Jong, T., & Elen, J. (2017). The effect of surprising events in a serious game on learning mathematics. *British Journal of Educational Technology*, 48(3), 860–877. <https://doi.org/10.1111/bjet.12458>
- Wynkoop, D. (2022). *Ratio and proportional reasoning of double-accelerated middle school math students* [Pennsylvania State University]. <https://etda.libraries.psu.edu/catalog/19304dqw5353>