JagoMIPA: Jurnal Pendidikan Matematika dan IPA
p-ISSN: 2797-6475, e-ISSN: 2797-6467
Volume 6, nomor 3, 2026, hal. 2440-2448
Doi: https://doi.org/10.53299/jagomipa.v6i3.4046

Goal-Free and Goal-Given Problems: Effects on Students' Retention, Transfer Ability, and Cognitive Load

Fregita Habuke*, Endah Retnowati
Universitas Negeri Yogyakarta, Indonesia

*Corresponding Author: fregitahabuke2022@student.uny.ac.id
Dikirim: 09-03-2026; Direvisi: 26-07-2026; Diterima: 28-07-2028

Abstract: This study aims to examine and describe the effect of goal-free problem presentation design on students' retention, transfer, and cognitive load abilities. This study uses a quantitative approach with a fully randomized experiment design. There were 111 participants in this study, all of whom were students from a junior high school in Yogyakarta. The material used in this study was the angle theorem and the relationship between angles on parallel lines cut by a transversal line. Learning was carried out in three phases, namely the introductory phase, the acquisition phase, and the test phase. The data analysis used was ANCOVA (Analysis of Covariance) with initial ability scores as covariates. The instruments used were retention and transfer ability tests and a cognitive load measurement scale at the end of the questions. Data analysis focused on the presentation design of goal-free problems and goal-given problems. The results showed that the presentation design of problems had an effect on retention ability. Learning using the presentation design of goal-given problems was better than goal-free problems in terms of retention ability.

Keywords: cognitive load; goal-free problems; goal-given problems; retention; transfer.

Abstrak: Penelitian ini bertujuan untuk menguji dan mendeskripsikan pengaruh desain penyajian masalah goal free problems dibandingan dengan goal given problems terhadap kemampuan retensi, kemampuan transfer, dan cognitive load siswa. Penelitian ini menggunakan pendekatan kuantitatif dengan jenis penelitian *fully randomized experiment*. Partisipan dalam penelitian ini sebanyak 111 siswa yang berasal dari salah satu Sekolah Menengah Pertama di Kota Yogyakarta. Materi yang digunakan dalam penelitian ini adalah teorema sudut dan hubungan antarsudut pada garis sejajar yang dipotong oleh garis transversal. Pembelajaran dilakukan melalui tiga fase yaitu fase *introductory*, fase *acquisition*, dan fase *test*. Analisis data yang digunakan adalah ANCOVA (*Analysis Of Covariance*) dengan nilai kemampuan awal sebagai kovariat. Instrumen yang digunakan adalah tes kemampuan retensi dan transfer, skala pengukuran *cognitive load* pada akhir butir soal. Analisis data difokuskan pada desain penyajian masalah goal free problems dan goal given problems. Hasil penelitian diperoleh bahwa terdapat pengaruh desain penyajian masalah terhadap kemampuan retensi. Pembelajaran menggunakan desain penyajian masalah goal given problems lebih baik daripada goal free problems terhadap kemampuan retensi.

Kata Kunci: *cognitive load; goal free problems; goal given problems; retensi, transfer.*

INTRODUCTION

Mathematics not only teaches students to calculate or solve problems but also trains them to think logically, analytically, and critically. Some mathematics material is complex, such as geometry, especially topics related to lines and angles. Geometry is considered quite difficult because it requires more than just cognitive abilities; it also requires visual abilities (Riastuti et al., 2017). A high level of complexity will increase students' cognitive load during learning. This will reduce students' ability to effectively construct knowledge during learning (Sweller et al., 2011). Therefore, learning should be well designed and take into account working memory capacity so that students can maximize their knowledge construction. The cognitive load that occurs during learning can be regulated using cognitive load theory. Cognitive load theory focuses on the cognitive structure of humans (Sweller et al., 2011). There are three types of cognitive load, namely intrinsic cognitive load, extraneous cognitive load, and germane cognitive load. Intrinsic cognitive load in learning is the level of complexity in the teaching materials provided. The complexity of the material comes from the type of learning material itself, and its complexity is also determined by students' prior knowledge. Extraneous cognitive load in learning is determined by the presentation of the teaching materials.

Cognitive load increases when unnecessary demands are placed on the cognitive system, such as inadequate instructional design, unnecessary environmental distractions, and even self-doubt. In addition, cognitive load can increase due to germane processes resulting from complex intrinsic processing (Paas & van Merriënboer, 2020). Goal-free problems are one learning strategy that can minimize extraneous cognitive load, thereby enabling improved problem-solving skills (Ayres, 1993). Goal-free problems are a problem-solving learning strategy designed to eliminate the ultimate goal of the problem given. By not determining the ultimate goal of the problem, students are guided to construct and develop solutions in problem solving using information known from the problem, so that students learn to think logically by applying the mathematical theorems they have learned.. Purnama & Retnowati (2020) concluded that students who learn using goal-free problems have better retention scores than those who learn using goal-given problems and experience lower cognitive load. By using goal-free problems, students will not use means-end analysis, thereby minimizing extraneous cognitive load. The problem-solving process in novice students causes them to use means-ends analysis strategies. As a result, students make many mistakes when determining subgoals.

Goal-given problems ask students to solve for a specific variable (the ultimate goal), as a result, novice students tend to use a working backward strategy to solve problems by creating sub-goals from the ultimate goal. Meanwhile, goal-free problems not only direct beginner students to develop previously learned knowledge into more complex knowledge by avoiding working backward, but also allow students to solve more variables in problems from known values (Retnowati & Maulidya, 2018). By preventing students from using the means-ends analysis strategy, the goal-free problem strategy is effective in terms of transferability and cognitive load (Sugiman et al., 2019). The goal-given problem design, which requires students to use the means-ends analysis strategy, can reduce student motivation (Van Harsel et al., 2020).

The main activity of learning mathematics is problem solving (Retnowati et al., 2010). Problem-solving skills are important for students to have in order to solve the problems they encounter. Problem-solving skills are defined as the ability to use mathematical concepts, procedures, facts, and tools to explain and predict a phenomenon, which includes the steps of formulating a mathematical situation, using or applying (formulas, facts, procedures, and reasoning), and interpreting (and evaluating the final results) (OECD, 2018). Students' failure to achieve higher-order thinking skills is caused by an inability to transfer knowledge (Tanudjaja & Doorman, 2020). Students fail to solve problems because of their inability to recognize problems and transfer the knowledge they have learned. Students are constrained in solving mathematical problems with complex questions that require more concepts to be connected and have a different structure from what they have mastered, which can result in low transfer abilities (Agustin et al., 2022). When students use their existing knowledge to solve problems they have never encountered before, transfer has occurred (Mayer, 1999). This means that when students solve problems, it can be said that they have been able to transfer their knowledge. This is in line with Kalyuga et al. (2012) who state that students who do not have prior knowledge that can be recalled to solve new problems have failed to transfer their knowledge, which is common among beginner students.

Presenting learning material without considering the principles of cognitive load theory will result in extraneous cognitive load. Learning that does not consider working memory capacity can result in high cognitive load, which is considered detrimental to students. Retention requires students' ability to remember what they have learned (Mayer, 2002). Not only is transfer ability lacking, but retention ability is also low. Students with good prior knowledge when given complex material will experience high cognitive load, and this is caused by intrinsic cognitive load. Therefore, this study was conducted to test and describe the effect of the presentation design of goal-free problems compared to goal-given problems on students' retention ability, transfer ability, and cognitive load.

RESEARCH METHOD

This study uses a quantitative approach with a fully randomized experiment design. It employs a 2×2 factorial experimental design involving two independent variables, namely problem presentation design (goal-free problems vs. goal-given problems) and social persuasion (with social persuasion vs. without social persuasion). From this experimental design, four experimental groups were formed, namely goal-free with social persuasion, goal-free without social persuasion, goal-given with social persuasion, and goal-given without social persuasion. Although the study had four groups, this article specifically focused its analysis on the main effect of the problem presentation design (goal-free vs. goal-given) on student retention, transfer, and cognitive load.

The participants in this study were 111 students from a junior high school in Yogyakarta. The researchers randomized the students using a random generator so that each class was divided into two experimental groups. This process aimed to control external variables and ensure uniformity in the initial characteristics between groups, so that differences in results could be interpreted as a result of the treatment given. The participants in this study were students who had not yet studied the material on the relationship between angles formed by two parallel lines intersected by a transversal line. The results of the development of the presentation design for goal-free problems and goal-given problems are presented in the following figure.

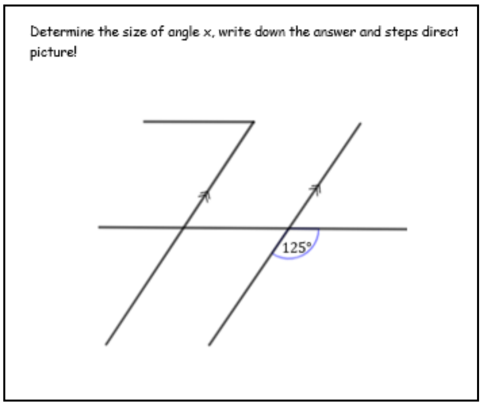

Figure 1. Example of goal free problems

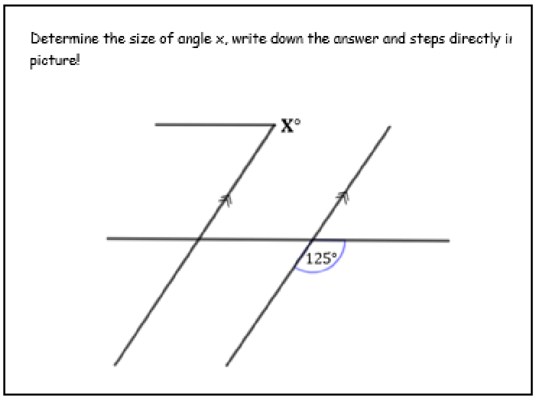

Figure 2. Example of goal given problems

PROCEDURE

This study was conducted once for all phases with a time allocation of 120 minutes. In the implementation stage, there were three phases, namely (1) the introductory phase; (2) the acquisition phase; and (3) the test phase. In the introductory phase, learning was carried out to activate prior knowledge by providing prerequisite material so that students learned and recalled the material that had been studied. This phase was carried out for 35 minutes. In the acquisition phase, students were given treatment with strategies that had been determined in advance according to their experimental class. This phase lasted 40 minutes. Then, the test phase was carried out by measuring the extent to which students understood the material using retention and transfer ability tests, followed by students' self-rating of cognitive load for each question. This test was carried out for 35 minutes, with 15 minutes for the retention ability test and 20 minutes for the transfer ability test.

Scoring

In measuring retention and transfer abilities, a three-level scoring rubric was applied, namely a score of 0 for incorrect or inappropriate answers, a score of 0.5 for answers that showed partial correctness but were still incomplete or contained errors, and a score of 1 for answers that were completely correct and met the assessment criteria. Meanwhile, students' cognitive load was measured using a self-rating instrument in the form of a Likert scale, as previously used in research by Leppink et al. (2013) with a score range of 1 (very, very easy) to 9 (very, very difficult). The self-rating used to measure students' cognitive load is presented in the following figure.

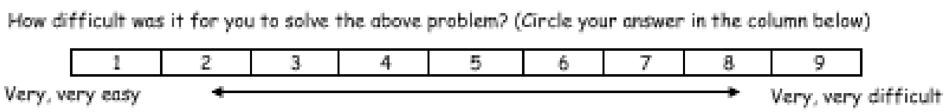

Figure 3. Self-rating cognitive load

Validity and reliability

Instrument validity testing was conducted through expert judgment, resulting in instruments that were valid in terms of logical validity and face validity. Face validity was obtained through evaluation of the appearance and format of the instruments, while logical validity was determined through a review of the suitability of the questions with the indicators used to measure specific aspects. Instrument reliability describes consistency or consistency. A reliable instrument describes the consistency or stability of a test score (Jhonson & Christensesn, 2014). Cronbach's alpha is an alpha coefficient as a general measure of the internal consistency of a multi-item scale (Field, 2009). The reliability results in this study are described in the following table.

Table 1. Reliability Test Result of Research Instruments

Research Instrument	Koefisien Alpha cronbach
Retention ability	0.730
Transfer ability	0.743
Cognitive load retention	0.840
Cognitive load transfer	0.873

Based on these results, the test instruments in this study were found to be sufficiently reliable for use.

Data Analysis

The data analysis technique used in this study was Analysis of Covariance (ANCOVA) with the aim of testing whether there were differences in means between two or more groups, taking into account confounding variables or covariates that might influence the results. The covariate in this study was the pretest results given after the introductory phase. Before the ANCOVA analysis was performed, assumption tests were conducted, including tests of independence, normality, homogeneity of variance, linear relationship between covariates and dependent variables, and homogeneity of regression slope. The test results showed that all assumptions were met ($p > 0.05$).

RESULT AND DISCUSSIONS

Result

Testing the main effect of the problem presentation design factor showed that there was a significant effect of the type of problem presentation on retention ability. In the transfer ability and cognitive load transfer tests, the type of problem presentation design had no significant effect. The results of testing the main factors of the problem presentation design are presented in the following table.

Table 2. Main Effect Result of Problem Presentation on Retention and Transfer Ability

	$df1$	$df2$	MSE	F	p	Partial eta-sq
Retention ability	1	107	0.917	4.918	**0.029**	0.044
Transfer ability	1	107	1,044	0,316	0,575	0,003

The average retention test scores of students who learned using the goal-given problems design were higher (M = 2.657, SD = 1.106) than those of students who learned using the goal-free problems design (M = 2.111, SD = 1.075). Thus, using the goal-given problems problem presentation design is better than the goal-free problems design in terms of retention ability. The following table shows the main test results of the problem presentation design on cognitive load retention and transfer.

Table 3. Main Effect Result of Problem Presentation on Cognitive Load Retention and Transfer Ability

	$df1$	$df2$	MSE	F	p	Partial eta-sq
Cognitive load retention	1	107	2,743	0,234	0,629	0,002
Cognitive load transfer	1	107	3,641	0,123	0,727	0,001

DISCUSSION

The results of the study indicate that problem presentation design has a different effect on students' cognitive aspects. There is a significant difference in the effect between goal-free problems and goal-given problems on retention ability. These findings support the cognitive load theory framework, which emphasizes the importance of optimizing germane cognitive load and minimizing extraneous cognitive load to support the construction and storage of schemas in long-term memory (Paas, Renkl, et al., 2004; Kirschner, 2002). This is in line with Sweller's (1994) opinion that germane cognitive load increases when information is considered directly relevant to schemas, and this is necessary for the construction and storage of schemas in long-term memory (Kirschner, 2002). This means that it is important to optimize germane cognitive load and minimize extraneous cognitive load in designing learning so that the objectives of learning can be achieved. Goal-free problems can minimize extraneous cognitive load, allowing working memory to function more optimally in constructing knowledge. However, unlike previous findings, the goal-free problem design in this study did not show any advantages in terms of retention or transfer abilities. This indicates that the freedom of exploration offered by goal-free problems does not always reduce cognitive load, but can increase element interactivity when the complexity of the problem and the amount of information that must be integrated exceed the working memory capacity of students (Chen et al., 2018).

Goal-free problem designs require students to explore various possible solutions without an explicit end goal, thereby increasing the demands on information processing and contributing to a high level of interactivity. This condition has the potential to exhaust working memory capacity and hinder the formation of stable knowledge schemas. Similarly, goal-given problem designs that direct students toward a specific goal encourage the use of means-ends analysis strategies through a continuous process of looking back. Although this strategy is effective for novice learners, the resulting cognitive load remains high due to the demands of continuous information matching (Sweller et al., 2011). These findings explain why goal-free problem design does not significantly affect retention and transfer abilities, and why goal-given problem design only significantly affects retention abilities, but not transfer. In retention tests, the similarity between test questions and the acquisition phase allows for a reduction in intrinsic cognitive load and an increase in germane cognitive load through the application of previously acquired knowledge (Van Merrienboer et al., 2005).

Furthermore, the absence of differences in the effects of goal-free problems and goal-given problems on cognitive load in retention and transfer tests indicates that both designs contribute to relatively high cognitive load. This finding confirms that limitations in working memory capacity are a determining factor when element interactivity and task complexity increase, so that learning has the potential to be inhibited even though the learning design is different (Sweller et al., 1998; De Jong, 2010). The processing of intrinsic and extraneous information that exceeds the capacity of working memory results in insufficient space to process all incoming information, causing students to experience cognitive load (Khalil et al., 2005; Sweller et al., 1998). This is in line with Chen et al. (2021), who stated that increased cognitive load is not caused by high interactivity elements but by the depletion of working memory capacity during learning. The continuous presentation of problems with high interactivity elements results in high cognitive load (Ayres, 2006). Thus, the increase in cognitive load in this study was more due to the depletion of working memory capacity than differences in the characteristics of the problem presentation design itself (Ayres, 2006; Chen et al., 2021; Sugiman et al., 2019).

LIMITATION STUDY

This study has several limitations that need to be considered when interpreting the findings and generalizing the results. First, the complexity of the problems used in the goal-free and goal-given problem designs is relatively high and contributes to a high degree of interactivity. This condition has the pote This study has several limitations that need to be considered when interpreting the findings and generalizing the results. First, the complexity of the problems used in the goal-free and goal-given problem designs is relatively high and contributes to a high degree of interactivity. This condition has the potential to dominate the working memory capacity of students, so that the effects of problem presentation design and social persuasion cannot appear optimally. Thus, the findings of this study more closely reflect a learning context with a high cognitive load and may not necessarily apply to tasks with low to moderate levels of complexity.ntial to dominate the working memory capacity of students, so that the effects of problem presentation design and social persuasion cannot appear optimally. Thus, the findings of this study more closely reflect a learning context with a high cognitive load and may not necessarily apply to tasks with low to moderate levels of complexity.

Second, cognitive load measurement in this study was conducted during the test phase (retention and transfer), not during the learning process itself. This approach limits our understanding of the dynamics of cognitive load experienced by students during the acquisition phase, when problem presentation design and social persuasion were directly applied. As a result, this study did not fully capture the fluctuations in cognitive load that may occur during the process of knowledge schema formation.

CONCLUSION

This study concludes that problem presentation design has an effect on retention ability. Goal-given problem design shows a significant effect on retention ability, while goal-free problem design shows no significant effect on retention ability or transfer ability. Thus, this study shows that the effectiveness of problem presentation design is highly dependent on the suitability between task complexity, working memory capacity, and learning objectives.

REFERENCES

Agustin, A., Retnowati, E., & Ng, K. T. (2022). *The transferability level of junior high school students in solving geometry problems*. Journal of Innovation in Educational and Cultural Research, 3(1), 59–69. https://doi.org/10.46843/jiecr.v3i1.57

Ayres, P. (2006). Impact of reducing intrinsic *cognitive load* on learning in a mathematical domain. Applied Cognitive Psychology, 20(3), 287–298. https://doi.org/10.1002/acp.1245

Ayres, P. L. (1993). *Why Goal-free problems Can Facilitate Learning. Contemporary Educational Psychology*, 18(3), 376–381. https://doi.org/10.1006/ceps.1993.1027

Chen, O., Castro-Alonso, J. C., Paas, F., & Sweller, J. (2018). Undesirable difficulty effects in the learning of high-element interactivity materials. Frontiers in Psychology, 9, Article 1483. https://doi.org/10.3389/fpsyg.2018.01483

Chen, O., Paas, F., & Sweller, J. (2021). Spacing and interleaving effects require distinct theoretical bases: a systematic review testing the *cognitive load* and discriminative-contrast hypotheses. Educational Psychology Review, 33(4), 1499–1522. https://doi.org/10.1007/s10648-021-09613-w

De Jong, T. (2010). *Cognitive load theory, educational research, and instructional design: Some food for thought*. Instructional Science, 38(2), 105–134. https://doi.org/10.1007/s11251-009-9110-0

Field, A. (2009). Discovering statistics using IBM SPSS statistics. London: Sage.

Jhonson, B., & Christensesn, L. (2014). Educational Research: quantitative, qualitative, and mixed approaches (5th Ed). SAGE Publication.

Kalyuga, S., Rikers, R., & Paas, F. (2012). *Educational implications of expertise reversal effects in learning and performance of complex cognitive and sensorimotor skills*. Educational Psychology Review, 24(2), 313–337. https://doi.org/10.1007/s10648-012-9195-x

Kirschner, P. A. (2002). *Cognitive load* theory: Implications of *cognitive load* theory on the design of learning. Learning and Instruction, 12(1), 1–10. https://doi.org/10.1016/S0959-4752(01)00014-7

Likourezos, V., & Kalyuga, S. (2017). *Instruction-first and problem-solving-first approaches: Alternative pathways to learning complex tasks*. Instructional Science, 45(2), 195–219. https://doi.org/10.1007/s11251-016-9399-4

Mayer, R. E. (2002). *Rote versus meaningful learning. Theory into Practice*, 41(4), 226–232. https://doi.org/10.1207/s15430421tip4104_4

OECD. (2018). PISA 2021 *Mathematics Framework* (Draft). https://www.oecd.org/pisa/pisaproducts/pisa-2021-mathematics-frameworkdraft.pdf

Ormrod, J., Anderman, E., & Anderman, L. (2017). Educational psychology: Developing learners. In Pearson (Ninth Edit). Pearson educational Limited.

Paas, F, Renkl, A., & Sweller, J. (2004). *Cognitive load* theory: *Instructional implications of the interaction between information structures and cognitive architecture*. Instructional Science, 32(1–2), 1–8. https://doi.org/10.1023/b:truc.0000021806.17516.d0

Paas, F., & van Merriënboer, J. J. G. (2020). *Cognitive-load theory: Methods to manage working memory load in the learning of complex tasks*. Current Directions in Psychological Science, 29(4), 394–398. https://doi.org/10.1177/0963721420922183

Pintrich, P. R., & Groot, E. V. De. (1990). Motivational and self-regulated learning components of classroom. Journal of Educational Psychology, 82(1), 33–40. https://doi.org/https://psycnet.apa.org/doi/10.1037/0022-0663.82.1.33

Purnama, P. W., & Retnowati, E. (2020). *The effectiveness of goal-free problems for studying triangle similarity in collaborative groups*. JRAMathEdu (Journal of Research and Advances in Mathematics Education), 6(1), 32–45. https://doi.org/10.23917/jramathedu.v6i1.11198

Retnowati, Endah, Ayres, P., & Sweller, J. (2010). *Worked example effects in individual and group work settings. Educational Psychology*, 30(3), 349–367. https://doi.org/10.1080/01443411003659960

Retnowati, E., & Maulidya, S. R. (2018). *Designs of goal-free problems for trigonometry learning. Journal of Physics: Conference Series,* 983(1). https://doi.org/10.1088/1742-6596/983/1/012125

Riastuti, N., Mardiyana, & Pramudya, I. (2017). *Analysis of students geometry skills viewed from spatial intelligence*. 020024. https://doi.org/10.1063/1.5016658

Sugiman, Retnowati, E., Ayres, P., & Murdanu. (2019). *Learning goal-free problems: Collaboratively or individually?* Cakrawala Pendidikan, 38(3), 590–600. https://doi.org/10.21831/cp.v38i3.26914

Sweller, J. (2011). *Cognitive load theory*. In H. G. Bower (Ed.), Psychology of learning and motivation: Advances in research and theory (1st ed., pp. 37–76). Elsevier Inc. https://doi.org/10.1016/B978-0-12-387691-1.00002-8

Usher, E. L., & Pajares, F. (2009). Sources of self-efficacy in mathematics: A validation study. Contemporary Educational Psychology, 34(1), 89–101. https://doi.org/10.1016/j.cedpsych.2008.09.002

Van Harsel, M., Hoogerheide, V., Verkoeijen, P., & Van Gog, T. (2020). *Examples, practice problems, or both? Effects on motivation and learning in shorter and longer sequences. Applied Cognitive Psychology*, 34(4), 793–812. https://doi.org/10.1002/acp.3649

Van Merriënboer, J. J. G., & Sweller, J. (2005). *Cognitive load* theory and complex learning: Recent developments and future directions. Educational Psychology Review, 17(2), 147–177. https://doi.org/10.1007/s10648-005-3951-0