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Cognitive Load Theory: Mathematical Resilience in a Variable Examples-Based Learning

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Abstract: Cognitive load theory is an instructional design theory which emphasizes the limited nature of working memory's capacity to process information. Germane cognitive load supports learning in which students do continuous efforts in understanding learning materials. Continuous efforts to get the desired results are called resilience. The fact is that prospective Mathematics teachers have limited interest in understanding difficult material while interest is very closely related to resilience. This limited interest results in less optimal efforts. This research is a qualitative descriptive study which aims at describing aspects of resilience in Germane cognitive load-based learning by using variable examples. The findings showed that the stages of learning based on cognitive load with variable examples were giving orientation to the learning material, organizing the variable examples, giving assistance to the work completion, presenting the results, and evaluating. As conclusion, aspects of resilience that appear in cognitive load-based learning are perseverance, adaptiveness, creativity, self-motivation, curiosity, and self-control.

Keywords: cognitive load, resilience, variable examples-based learning.

Abstrak: *Teori beban kognitif merupakan teori pembelajaran yang menekankan pada sifat terbatasnya kemampuan memori kerja dalam pemrosesan informasi. Beban kognitif germane merupakan salah satu yang mendukung dalam pembelajaran sehingga peserta didik memiliki usaha yang terus menerus dalam memahami materi. Usaha yang terus menerus dilakukan sampai mendapatkan hasil yang diinginkan disebut resiliensi. Permasalahan yang terjadi adalah calon guru matematika memiliki minat yang terbatas dalam memahami materi yang sulit. Minat sangat berhubungan erat dengan resiliensi. Minat yang terbatas ini mengakibatkan usaha yang dilakukan calon guru matematika kurang maksimal dalam memahami materi. Penelitian ini merupakan penelitian deskriptif kualitatif dengan tujuan untuk mendeskripsikan aspek resiliensi dalam pembelajaran berbasis beban kognitif Germane dengan menggunakan variable examples. Hasil penelitian menunjukkan tahapan pembelajaran berbasis beban kognitif dengan variable exemples adalah orientasi pada materi, mengorganisasi untuk variable exemples, membimbing pengerjaan, menyajikan hasil, dan mengevaluasi. Kesimpulan dalam penelitian ini adalah aspek resiliensi yang muncul dalam pembelajaran berbasis beban kognitif adalah aspek ketekunan, daya adaptasi, kreativitas, motivasi diri, rasa keingintahuan, dan kontrol diri.*

Kata kunci: *beban kognitif, resiliensi, pembelajaran berbasis contoh variable.*

▪ INTRODUCTION

Learning is a process of interaction between students, educators, and learning resources in a learning (Permendikbud No 103 Tahun 2014). It provides an opportunity for students to construct a knowledge having been learned (Subanji, 2011). The new constructed knowledge can be connected with students' prior knowledge. The connected knowledge is, then, processed in a cognitive system. Cognitive is a mental process involving the activities of connecting, assessing, and considering an event. The cognitive system has described an Information Processing Theory coinned by Sweller (2016) that is to find out the stages in knowledge construction. Information Processing Theory is

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structured by the limited capacity of working memory (short-term memory) and the unlimited capacity of long term memory to process information (İbili, 2019; İbili & Billinghurst, 2019; Sweller et al., 2019).

This limited working memory capacity is hereinafter referred to as cognitive load. Cognitive load is defined as the effort of working memory in processing information. There were three types of cognitive load, namely intrinsic, extraneous, and germane cognitive load (Kirschner et al., 2018). Intrinsic and extraneous cognitive loads are suppressed in learning as much as possible and vice versa for germane cognitive load which is increased in learning (Lin & Lin, 2014). Intrinsic and extraneous cognitive loads tend to hinder the learning process and vice versa while germane cognitive load tends to support learning process (de Jong, 2010).

Germane cognitive load is the cognitive load coming from the effort expended by working memory in processing information (Gupta, 2019; Gupta & Zheng, 2020; Kalyuga, 2011). It is very beneficial and can make a positive contribution in learning. It has variable aspects of examples and imagination (Sweller et al., 2011; Zheng et al., 2022). These aspects give an impact on learning that make efforts poured out continuously. Such efforts are called resilience in learning.

Resilience is a positive attitude to overcome anxiety from a challenge in problem solving which is continuously attempted until it finds results (Asih et al., 2019). Resilience gives positive impact on students' interest, enthusiasm, and efforts (Cahyani et al., 2018). There are 6 aspects of resilience, namely perseverance, adaptivity, creativity, self-motivation, curiosity, and self-control (Asih et al., 2019). Resilience can be known through indicators of resilience having been adopted from the aspects of resilience in problem-based learning (Yohanes & Darmawan, 2022) as seen in table 1. Resilience is a very important aspect in learning Mathematics.

Table 1. Resilience indicators

Aspects of Resilience	Indicators
Perseverance	- Make continuous efforts to achieve success. - Collaborate similar answers or collaborate other students' answers. - Confirm or consult the answers to the teacher/mentor (in this case the researchers).
Adaptivity	- Interact with other students. - Interact with the researchers. - Give helps to others.
Creativity	- Integrate various method or ideas to solve problems. - Create new ideas.
Self-Motivation	- Learn from failures in problem solving. - Believe that every problem has solution.
Curiosity	- Make reflection in every step. - Looking for similar answers. - Make use of various learning resources.
Self-Control	- Aware when his/her written or oral language easy or difficult to be understood by others. - Aware that his/herself has a problem.

Both resilience and germane cognitive load constitute components of learning theory that gives positive impacts to learning. Resilience is an aspect of the student's personality that is devoted continuously to understand the material being studied. Germane cognitive load is an instructional designed for students to devote their efforts to understanding the material. Germane resilience and cognitive load are connected to each other in learning activities. Started from here, this research was conducted with the aim of describing the relationship of mathematical resilience in a variable examples-based learning of germane cognitive load theory.

▪ METHOD

Participants

This descriptive qualitative research aiming at analyzing the relationship of mathematical resilience in a variable examples-based learning of germane cognitive load theory was conducted at Mathematics Education Study Program, Faculty of Mathematics and Natural Sciences - PGRI University of Banyuwangi. The research population were students of 2020 in the Even Semester of the 2022/2023 academic year. Population in this study amounted to 18 students. The research subjects (samples) are students who demonstrate aspects of resilience in learning. The research subjects were seen through observation sheets in learning.

Research Design and Procedures

The research was conducted in the School Mathematics course to be able to provide learning with variable examples models. The syntax for variable examples-based learning is adopted from Problem-Based Learning syntax in Mathematics that has been developed by Yohanes & Darmawan (2022). The researchers started the research by teaching School Mathematics course using variable examples-based learning. Such learning considered as one indicator of germane cognitive load of variable examples. The learning syntax was adopted from problem-based learning in research (Yohanes & Darmawan, 2022).

Table 2. Synchronization of varible examples syntax with mathematic resilience aspects

No	Variable Examples Syntax	Resilience Aspects
1	Giving orientation to the Learning Material.	Self-Motivation
2	Organizing the Variable Examples.	Self-Control, Adaptivity
3	Giving Assistance to the Work Completion.	Adaptivity, Perseverance, Self-control, Curiosity, Self-Motivation, Creativity
4	Presenting the Results.	Self-Control, Curiosity, Self-Motivation, Adaptivity
5	Evaluating	Perseverance, Adaptivity, Curiosity, Self Motivation, Self-Control

Instruments

The research used core instrument, namely the researchers themselves, and the supporting instruments, namely the researchers' notes, observation sheets, interview guides, and documentation. The researchers were in charged to design, conduct, and report the research. The researchers' notes were used to record aspects of resilience

emerged during learning. The observation sheet was used as a guide in observing research activities. Interview guidelines were used to explore aspects of resilience in learning. Documentation was done to archive in writing, video, or audio during the research.

Data Analysis

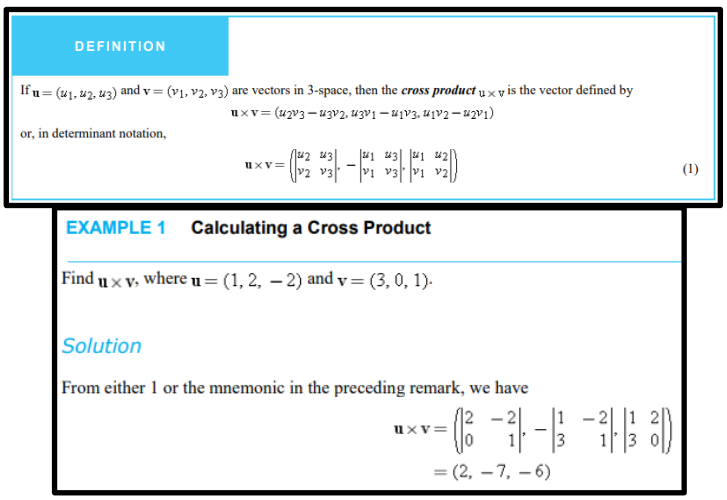
Data analysis was carried out using the method of checking the validity of the triangulation data. Data analysis was performed by using interactive data analysis techniques (Miles et al., 2014). It was carried out since data collection began by creating resilience categories in a learning based on variable examples. The raw data obtained were then reduced in such a way that it was presented to finally be concluded.

▪ RESULTS AND DISCUSSION

The research was conducted on a learning that emphasizes the cognitive load of germane variable examples. Cognitive load-based learning is a learning that considers the importance of increasing germane cognitive load and suppressing intrinsic and extraneous cognitive loads in learning (de Jong, 2010; Lin & Lin, 2014; TOPU, 2023a, 2023b). Activities in learning that can increase germane cognitive load from the opinion of several researchers such as Sweller et al are imagination and variable examples (Sweller, 2016; Sweller et al., 2019). Variable examples have a positive influence on learning to be able to devote effort continuously in understanding the material. Efforts that are used continuously in learning are called resilience.

Giving Orientation to the Learning Material

Resilience in cognitive load-based learning can be seen from the emergence of adaptivity, perseverance, self-control, curiosity, self-motivation, creativity at every step of learning. The research was carried out on cognitive load-based learning with the learning syntax as shown in table 1. The research was started by orienting the material about the cross product. The researcher begins by providing material in the form of definitions and examples of questions as shown in Figure 1 below.



DEFINITION

If $\mathbf{u} = (u_1, u_2, u_3)$ and $\mathbf{v} = (v_1, v_2, v_3)$ are vectors in 3-space, then the ***cross product*** $\mathbf{u} \times \mathbf{v}$ is the vector defined by

$$\mathbf{u} \times \mathbf{v} = (u_2v_3 - u_3v_2, u_3v_1 - u_1v_3, u_1v_2 - u_2v_1)$$

or, in determinant notation,

$$\mathbf{u} \times \mathbf{v} = \left(\begin{vmatrix} u_2 & u_3 \\ v_2 & v_3 \end{vmatrix}, -\begin{vmatrix} u_1 & u_3 \\ v_1 & v_3 \end{vmatrix}, \begin{vmatrix} u_1 & u_2 \\ v_1 & v_2 \end{vmatrix} \right) \quad (1)$$

EXAMPLE 1 Calculating a Cross Product

Find $\mathbf{u} \times \mathbf{v}$, where $\mathbf{u} = (1, 2, -2)$ and $\mathbf{v} = (3, 0, 1)$.

Solution

From either 1 or the mnemonic in the preceding remark, we have

$$\mathbf{u} \times \mathbf{v} = \left(\begin{vmatrix} 2 & -2 \\ 0 & 1 \end{vmatrix}, -\begin{vmatrix} 1 & -2 \\ 3 & 1 \end{vmatrix}, \begin{vmatrix} 1 & 2 \\ 3 & 0 \end{vmatrix} \right)$$

$$= (2, -7, -6)$$

Figure 1. Learning materials about cross product definition

The researcher delivered the learning material and the research subjects responded by asking questions. Questions to ask were about the definition of cross product that is connected with the determinants of the matrix. This questions can be seen from the following conversation.

The Researcher : Look at the two definitions of cross product. Do you think they have the same result?
Subject 1 : Looks similar, Sir.
The Researcher : Why do you think so?
Subject 1 : The first definition is an elaboration, Sir, while the second one is a metric. And it is a determinant symbol because it is flanked by one straight line. When I do the math problem with the second definition, the results are similar with those with the first definition. What do you think, Sir?
The Resercher : Excellent. Does it mean that it can determine the results of cross product?
Subject 1 : Insya Allah, Sir, I'll try it later.

The provided learning material, as shown in Figure 1, was using English. Mathematical learning material in English poses a problem in itself for Mathematics Education students. The use of such learning material actually provides an extraneous cognitive load from the results of research previously conducted by (Yohanes & Yusuf, 2021a). Eventhough it gives a bad load, resilience in this learning process is still seen in self-motivated attitudes. Conversation 1 with bold and underlined print showed that the research subject has confidence that the given questions can be resolved. Interest of Mathematics teacher candidates in this learning has a positive relationship to resilience (Asih et al., 2019) so that the orientation step on the material shows the self-motivated attitude of the research subjects to understand the cross product material.

Organizing Variable Examples

The researcher feels that the research subject had already understood the learning material and then the researcher organized the sample variables used to deepen understanding. Variable examples are elements of germane cognitive load in learning. Variable examples have a positive impact on learning.This study uses 4 sample variables as shown in Figure 2 below.

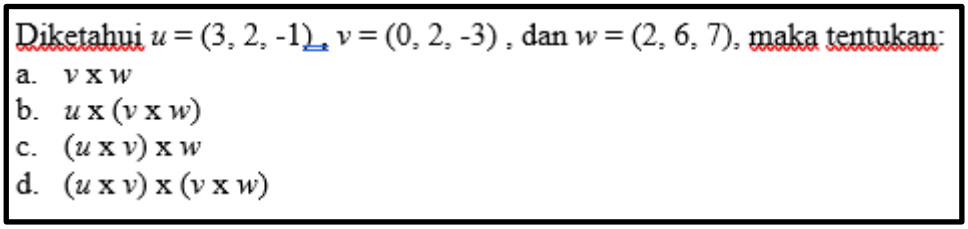

Diketahui $u = (3, 2, -1)$, $v = (0, 2, -3)$, dan $w = (2, 6, 7)$, maka tentukan:
a. $v \times w$
b. $u \times (v \times w)$
c. $(u \times v) \times w$
d. $(u \times v) \times (v \times w)$

Figure 2. Variable examples in cross product learning

Giving variable examples as learning material made the research subjects faced some difficulties so they asked help from the researchers and their fellow friends. These

difficulties can be overcome by the subject of learning. Efforts to overcome these difficulties are part of the resilience aspect. The conversation can be seen from the following conversation 2.

The Researcher	: Do you have any questions about the exercises?
Subject	: Is the operation on this vector the same with if we perform number operation, Sir? It seems that I have difficulties with point b-d.
Subject 2	: (raises hand) Excuse me, Sir. In my opinion, the one in brackets whould be operated first. So, Subject 1, it's the same as the number operation, that what's in brackets must come first. Isn't it like that, Sir?
The Researcher	: She's absolutely right, Subject 2. Your answer is so super. So students….do you think the answer of Subject 2 correct?
Simultaneously	: Obviously yes.

Variable examples are part of the germane cognitive load that encouraged students or the research subjects to devote their efforts to solve problems (Sweller et al., 2019). The provided sample variables will be understood by the research subjects and will be linked to their prior abilities (Asma & Dallel, 2020; Dervić et al., 2019). This activity showed that the aspect of self-control can be seen from the research subjects who are aware of the perceived difficulties. The results of conversation 2 with bold and underlined text showed that subject 1 faced difficulties with point b-d. These difficulties included intrinsic cognitive load (Yohanes & Yusuf, 2021b) which was also an aspect of self-control of research subjects. Subject 1 also interacted with the researchers and subject 2 so that it was seen that there were adaptive aspects that emerged from the research subject. Interaction between fellow research subjects is an adaptive aspect experienced by research subjects (Yohanes & Darmawan, 2022). Steps in organizing variable examples are seen in aspects of self-control and adaptability.

Giving Assistance the Work Completion

The researchers provided a chance for students to work on the given sample variables. The researchers welcomed some questions to ask and invited the students to have discussions with friends or look for references on the internet or books. The results of observation showed that the research subjects discussed with each other and if they faced difficulties they directly asked the researchers. Figure 3 showed how the subject conducted discussions and sought references.

Figur 3. Interaction between research subjects and reference search activities from the internet or from books

Some research subjects came to the researchers to ask questions about the sample variables being worked on. It seems that they faced difficulties regarding work that uses the first definition (operations between vector elements) or the second definition (matrix determinants). The difficulties can be seen from the following conversation:

The Subject 3 : Excuse me, Sir. I have a question (He was approaching the researcher with subject 4)
The Researcher : OK. What can I help you?
The Subject 3 : It seems that both of us having different way in solving the problem.
The Subject 4 : Yes, Sir. I make use of the first definition while he uses the second one.
The Researcher : OK. Question for subject 3 is….Do you get the same result with subject 4?
The Subject 3 : Wait a minute, Sir. I will finish my calculation. Some more minutes, Sir.
The Subject 5 : I have the same result with subject 4 although my way of work was similar with subject 3 (Then he went back to his desk)
The Subject 3 : It turns out to be the same, Sir..
The Researcher : So…..the problems have already resolved, right? It is good to apply different methods. It shows that you have mastered the mathematical concepts well.

The research subjects held discussions with fellow friends and also looked for references on the internet using their respective cell phones. Aspects of adaptivity, perseverance, and curiosity can be seen from Figure 3 (Al Ghifari et al., 2022). In the meantime, difficulties were also got by the research subjects at this stage which can be seen from conversation 3 between subject 3 and 4 (Dan & Reiner, 2017; Geng & Yamada, 2020). Subject 3 faced difficulties so that aspect of self-control was seen from the efforts made (Conversation 3 in bold and underlined print). Subject 3 was also looking for the correct answer which can be seen from conversation 3 in bold and italics. It can be seen that the curiosity aspect is seen from this stage (Paoletti et al., 2019). Subject 3 can also be seen from conversation 3 with the underline feeling self-motivated and confident of being able to get the correct answer (Okuni & Widyanti, 2019). Subject 4 and 3 in conversation 3 used several ways to find the desired results. The creative aspect is seen because the subject uses several methods in the work.

Presenting the Results

The researchers provided a chance for the research subjects to present the operation results on the whiteboard. Subjects are welcome to present simultaneously on the blackboard for points a and b in figure 2. It can be seen that the research subjects were very enthusiastic in presenting their performance as shown in Figure 4. The researchers gave opportunities for the research subjects to show the results of their performances on the whiteboard. This activity can be seen from conversation 4 as follows:

The Researcher : Who wants to work on the calculation on the whiteboard? Please do.

Subject 3 : It's me, Sir. I wonder whether my answer is correct or incorrect since I was confused, then. I will show you. But now I am sure, my answer is correct.
Subject 2 : What if I fix problem b, Sir? I have compared my answer with that of other students. It seems correct.
The Researcher : Yes, you may come forward together.

Figure 4. The research subjects were trying to show their performances in front of the class

Presenting the results or performance provided motivation to the research subjects as seen in Figure 4. They looked confident that they were able and had obtained the correct results so that they presented the results on the blackboard (Larmuseau et al., 2019). Conversation 4 with the text in bold and underlined also shows that the research subject has aspects of self-control because he realizes that he had experienced difficulties in doing the work (Apostolou & Linardatos, 2023). The subject also had an aspect of curiosity because he had asked his friends about the answers they had. Interaction with friends as seen from conversation 4 in bold and italic text shows curiosity and adaptivity aspects seen from the research subject.

Evaluating

In this stage, the researchers evaluated the performance resulted in the learning. The researchers saw that the research subjects gave correct and suitable answers according to the definitions given. The researchers looked at the results of the work displayed on the whiteboard one by one and invited all the research subjects to evaluate the performance results. Conversation 5 below is an overview of the discussion regarding the evaluation of the results of variable examples.

The Researcher : Attention, please. How is the performance result of subject 4? Is it correct or incorrect?
Subject 4 : Correct, correct, correct. Come on friends. What about you?
Subject 1 : The answer is correct, same with mine, but it seems to lack comma, Sir. This is a vector, right?
Subject 4 : What do you mean? Can you clarify your question, Subject 1?
Subject 1 : That's your final result, right? (32 -6 -4). It's lack of comma between 32 and -6, and between -6 and -4.

Subject 4	: Do you think so, Sir?
The Researcher	: Please have a look at your answer? Is it a vector or constanta?
Subject 4	: It's a vector, Sir.
The Researcher	: If it is a vector, then check about the way you write it. Is it correct? Please check the definition of vector I have given you.
Subject 4	: Wait, Sir…… Oh yes….it turns out that a vector should be put between brackets and there is a comma between the numbers. Subject 1 is correct. Thank you. I already understand it.
Peneliti	: Students…. have you understood now? It is important to remember that cross product will results a vector and it's different from dot product which results constantas.

Evaluation of the work of research subjects was carried out to ensure that the research subjects or students had understood the learning material (Virlan, 2022). Conversations between the research subjects and the researchers showed adaptivity aspect of the learning. Conversation 5 in bold and underlined shows the adaptivity and self-motivation aspects that the subject believed the answer was correct. The subjects also felt curious when instructions from other subjects occured. Conversation 5 in bold and italics shows that the subject is trying to understand the intention of subject 1. Subject 4 also has self-control when he knows that the answer is not entirely correct. It can be seen that in conversation 5 italics subject 4 is aware of the difficulties and differences in the answers (Gutiérrez et al., 2023). The self-control aspect was visible and the perseverance aspect was seen because from the conversation 5 the research subjects finally got the right answer.

▪ CONCLUSION

The researcher concludes that the resilience aspects appear in cognitive load-based learning with sample variables are perseverance, adaptivity, creativity, self-motivation, curiosity, and self-control. Aspects of resilience that appear in each step of learning based on cognitive load are (1) Giving orientation to the material with aspects of self-motivation; (2) Organizing variable examples with self-control and adaptivity aspects; (3) Giving assistance to the work completion with adaptivity, perseverance, self-control, curiosity, self-motivation, and creativity aspects; (4) Presenting the results with aspects of self-control, curiosity, self-motivation, and adaptability; and (5) evaluating with aspects of perseverance, adaptability, curiosity, self-motivation, and self-control.

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▪ REFERENCES

Al Ghifari, S. S., Juandi, D., & Usdiyana, D. (2022). *Systematic literature review: pengaruh resiliensi matematis terhadap kemampuan berpikir matematis tingkat tinggi* [systematic literature review: the effect of mathematical resilience toward mathematical higher order thinking skills]. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *6*(2), 2025–2039.

Apostolou, D., & Linardatos, G. (2023). Cognitive load approach to digital comics creation: a student-centered learning case. *Applied Sciences (Switzerland)*, *13*(13), 1–15.

Asih, K. S., Isnarto, Sukestiyarno, & Wardono. (2019). *Resiliensi matematis pada pembelajaran discovery learning dalam upaya meningkatkan komunikasi matematika* [mathematical resilience in discovery learning to upgrade mathematical communication]. *PRISMA, Prosiding Seminar Nasional Matematika*, *2*, 862–868.

Asma, H., & Dallel, S. (2020). Cognitive load theory and its relation to instructional design: perspectives of some algerian university teachers of english. *Arab World English Journal*, *11*(4), 110–127.

Cahyani, E. P., Wulandari, W. D., Rohaeti, E. E., & Fitrianna, A. Y. (2018). *Hubungan antara minat belajar dan resiliensi matematis terhadap kemampuan pemahaman matematis siswa kelas viii smp* [correlation between students' study interest & mathematical resilience toward mathematical understanding skill of junior high school students of class VIII]. *Jurnal Numeracy*, *5*(1), 49–56.

Dan, A., & Reiner, M. (2017). Real time eeg based measurements of cognitive load indicates mental states during learning. *Journal of Educational Data Mining*, *9*(2), 31–44.

de Jong, T. (2010). Cognitive load theory, educational research, and instructional design: some food for thought. *Instructional Science*, *38*(2), 105–134.

Dervić, D., Đapo, N., Mešić, V., & Đokić, R. (2019). Cognitive load in multimedia learning: an example from teaching about lenses. *Journal Of Education In Science Environment And Health*, *5*(1), 102–118.

Geng, X., & Yamada, M. (2020). The effects of augmented reality on learning performance and cognitive load using the spatial continuity principle. *17th International Conference on Cognition and Exploratory Learning in Digital Age (CELDA 2020)*, 235–242.

Gupta, U. (2019). Interplay of germane load and motivation during math problem solving using worked examples. *Educational Research: Theory and Practice*, *30*(1), 67–71.

Gupta, U., & Zheng, R. Z. (2020). Cognitive load in solving mathematics problems: validating the role of motivation and the interaction among prior knowledge, worked examples, and task difficulty. *European Journal of STEM Education*, *5*(1), 1–14.

Gutiérrez, Á., Blanco, P., Ruiz, V., Chatzigeorgiou, C., Oregui, X., Álvarez, M., Navarro, S., Feidakis, M., Azpiroz, I., Izquierdo, G., Larraga-García, B., Kasnesis, P., Olaizola, I. G., & Álvarez, F. (2023). Biosignals monitoring of first responders for cognitive load estimation in real-time operation. *Applied Sciences*, *13*(13), 7368.

İbili, E. (2019). Effect of augmented reality environments on cognitive load: pedagogical effect, instructional design, motivation and interaction interfaces. *International Journal of Progressive Education*, *15*(5), 42–57.

İbili, E., & Billinghurst, M. (2019). Assessing the relationship between cognitive load and the usability of a mobile augmented reality tutorial system: a study of gender effects. *International Journal of Assessment Tools in Education*, *6*(3), 378–395.

Kalyuga, S. (2011). Informing: A cognitive load perspective. *Informing Science: The International Journal of an Emerging Transdiscipline*, *14*(1), 33–45.

Kirschner, P. A., Sweller, J., Kirschner, F., & Zambrano, J. R. (2018). From cognitive load theory to collaborative cognitive Load Theory. *International Journal of Computer-Supported Collaborative Learning*, *13*(2), 213–233.

Larmuseau, C., Vanneste, P., Cornelis, J., Desmet, P., & Depaepe, F. (2019). Combining physiological data and subjective measurements to investigate cognitive load during complex learning. *Frontline Learning Research*, *7*(2), 57–74.

Lin, J. J. H., & Lin, S. S. J. (2014). Cognitive load for configuration comprehension in computer-supported geometry problem solving: an eye movement perspective. *International Journal of Science and Mathematics Education*, *12*(3), 605–627.

Lampiran Permendikbud no 103 tahun 2014, (2014). [appendix to the rules of education and culture ministry no. 103 year 2014 about elementary and high schools Learnings. 2014. Jakarta: PERMENDIKBUD]

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). Qualitative Data Analysis, A Methods Sourcebook (3rd ed.). Sage Publications.

Okuni, I. M., & Widyanti, A. (2019). International students' cognitive load in learning through a foreign language of instruction: a case of learning using bahasa - indonesia. *People: International Journal of Social Sciences*, *4*(3), 1503–1532.

Paoletti, T., Vishnubhotla, M., & Mohamed, M. (2019). Inequalities and systems of relationships: reasoning covariationally to develop productive meanings. *Proceedings of the 41st Annual Meeting of PME-NA*, 157–166.

Subanji. (2011). *Teori berpikir pseudo penalaran kovariasional* [covariational reasoning pseudo thinking theory]. UM Press.

Sweller, J. (2016). Working Memory, Long-term Memory, and Instructional Design. *Journal of Applied Research in Memory and Cognition*, *5*(4), 360–367.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). Cognitive load theory (Vol. 82, Issue 1). Cambridge University Press.

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 Years Later. *Educational Psychology Review*, *31*(2), 261–292.

Topu, F. B. (2023a). Effects of cognitive load level on students' attitude towards the gamified course. *Journal of Learning and Teaching in Digital Age*, *8*(1), 93–112.

Topu, F. B. (2023b). Effects of gamification on active and reflective learners' engagement and cognitive load. *Journal of Theoretical Educational Science*, *16*(1), 41–71.

Virlan, A. Y. (2022). The role of error correction in teaching and learning of english from the cognitive load perspective: A Case Study. *JET (Journal of English Teaching)*, *8*(2), 195–208.

Yohanes, B., & Darmawan, P. (2022). *Resiliensi matematis calon guru matematika dalam pembelajaran berbasis masalah* [mathematical resilience of prospective

mathematics teachers in problem-based learning]. *Jurnal Kajian Pembelajaran Matematika*, *6*(2), 96–107. http://journal2.um.ac.id/index.php/jkpm

Yohanes, B., & Yusuf, F. I. (2021a). Intrinsic cognitive load in online learning model of school mathematics 1 in covid-19 pandemic period. *JIPM (Jurnal Ilmiah Pendidikan Matematika)*, *9*(2), 59.

Yohanes, B., & Yusuf, F. I. (2021b). *Teori beban kognitif: peta kognitif dalam pemecahan masalah pada matematika sekolah* [cognitive load theory: cognitive maps in solving problems of schools mathematics]. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *10*(4), 2215.

Zheng, H., Jung, E., Li, T., & Yoon, M. (2022). Effects of Segmentation and Self-Explanation Designs on Cognitive Load in Instructional Videos. *Contemporary Educational Technology*, *14*(2).