The Cognitive Load of Learners in the Learning Process of the Rotating Object Volume

Wawan1a, E F Ningsih1, S A Widodo2, Leonard,3 R M Sary4, E Retnowati5

1Institut Agama Islam Ma’arif NU Metro Lampung, Lampung, Indonesia
2Universitas Sarjanawiyata Tamansiswa, Jl. Batikan UH III/1043
3Universitas Indraprasta PGRI, Jl. Nangka No 58C, Jakarta
4Universitas PGRI Semarang, Jl. Sidodadi Timur No 24, Semarang
5Universitas Negeri Yogyakarta, Jl. Gejayan, Yogyakarta

a)awanwawan@gmail.com

Abstract: This research is aimed to explore the cognitive load of learners in the learning process of rotating object volume as well as to provide alternative solutions in managing the intrinsic cognitive load, reducing the extraneous cognitive load as well as improving the germane cognitive load. This research was conducted in Muhammadiyah Purworejo Senior High School with the 3 (three) learners from XII grade as the subjects. The purposive sampling technique was used to determine the research subject. The data collecting method used were test and interview. The data were analyzed by using a qualitative descriptive analysis. This research has provided the results which show that the occurrence of intrinsic cognitive load in the learning process of a rotating object volume is caused by the amount of interactivity elements that have to be studied and the complexity of material learned. The interacting elements are Arithmetic, Algebra, the intersection between two curves, the concept and rule of integration, while the elements of material complexity are the difficulties in imagining the rotating object, and conducting the algebra operation. The occurrence of extraneous cognitive load in the learning process of rotating object volume is caused by the way of teacher delivering the meaningless materials as well as the absence of geometric illustration from the teaching performed by teacher. The next discussion is regarding the germane cognitive load in the learning process of rotating object volume, it is known that this cognitive load is very low. This condition is caused by the learning process in class that tends to be more conventional as well as the minimum activities of learners in studying the materials.

1. Introduction
An integral material is one of the primary materials in the learning curriculum of mathematics in the degree of High School in Indonesia. Decent ability in understanding the material will facilitate the learners in solving the mathematics problems associated with the integral concept, such as calculating the square and volume of irregular objects. Decent ability in understanding this material will also facilitate the learners in studying the other subject’s materials, such as physics, because this material is often associated to the materials in that subject. Kinematics motion with vector analysis and the degree of motion-change are the sample of physics materials which associated with the integral material. Even though, this material instead becomes the highly difficult material to be studied by learners. As an antiderivative, this material is considered as the most difficult between the other calculus materials [1].
According to the research of [2], it was revealed that the learners are having difficulties in solving the integral questions associated with a trigonometric function. The learners are discovered to be more focusing on the procedural aspect rather than the conceptual aspect. In general, the learners also have no comprehensions towards conceptual and procedural integrations. From this research, it is known as well that the highest amount of mistake conducted by the learners is the technical error caused by the lack of knowledge related to the mathematics materials which associated with an integral.

There are many conditions that cause the difficulties of learners regarding the integral material. Referring to the research results of [3], an information was acquired in which the difficulties and personal issues have become the reasons of a lower achievement on the mathematics learning. On the other case, the research results of [4] showed the results in which the learners tend to lack in mathematics skills such as number-facts, spatial and information visualization skills, thus, the learners are having difficulties in solving the high levels of mathematics problems.

Considering those conditions, then it is important for the mathematics teachers to understand the kind of mental processing of learners in receiving or studying the integral concepts and their applications. Related to this matter, thus, the cognitive load theory could become a reference for teachers in observing the mental activities of learners in solving the problems associated to integral.

The cognitive load theory is the mental effort that has to be conducted in the working memory to process the received information in a specific range of time [5–7]. The information processing in a human cognitive which later mentioned as the information processing theory. In this theory, it is explained that the main part of memory system that works in processing the received information is the short-term memory which also called as the working memory as well as the long-term memory or the permanent memory [8].

The long term memory is the part of memory system that contains long-term information, while the short-term memory is the storage system that able to load information in limited amount and in a limited time as well which caught by the conscious mind in a particular time. Discussing in further about this theory, the cognitive load is divided into three types, namely the intrinsic cognitive load, the extraneous cognitive load, and the germane cognitive load [5–7].

According to the perspective of this cognitive load theory, the author then interested to look more specifically on how the cognitive load of learners in the learning process of integral material, especially of what associated to the material of rotating object volume. By referring to this objective, the author has formulated One questions in this paper described as what is the profile of the cognitive load of learners in the learning process of rotating object volume?

2. **Literature Analysis**

According to [6,7], the cognitive load itself is the mental effort that has to be conducted in the working memory to process the received information in a particular range of time. On the other words, the cognitive load is the burden in conducting a certain task that generates impact on the cognitive processing system. By referring to the argument of [5], the Cognitive Load Theory (CLT) is aimed to predict the conditions that make the learning process to be successful and how it could effectively support by the teaching and instruction. Regarding its correlation to the learning process, the cognitive load theory states that the strengths and weaknesses of a human cognitive architecture are coming from the instructional design [9]. The next thing is according to this theory, the cognitive load is divided into three types, such as 1) intrinsic cognitive load, 2) extraneous cognitive load, and 3) germane cognitive load [5,6].

The intrinsic cognitive load and extraneous cognitive load are the cognitive loads that associated with the interactivity elements in the learning process while the germane cognitive load is the cognitive load associated with the mental effort which relevant to the comprehension towards a certain material. As what expressed by [10] that the intrinsic and extraneous cognitive loads will tend to disrupt the learning process, while the germane cognitive load is tend to support the learning process. In a more specific context, it can be said that if the intrinsic and extraneous cognitive loads are at the high level then the learning achievement of learners will be lower, meanwhile, if the germane cognitive load is at a high level then the learning achievement will be higher [11].

The next argument is [12] who argued that the occurrence of an intrinsic cognitive load in the learning process is caused by two factors, such as the interactivity element and the isolated/interacting element. The interactivity element is related to the high amount of correlated material topic while the isolated/interacting element is correlated with the complexity of the learned material.

The extraneous cognitive load is depending on the ways of delivering or presenting the materials to be learned. The way teacher delivering or presenting a material will influence the extraneous cognitive load. A better material presentation will decrease more cognitive load. On the other words, the presentation of a material which is not
properly designed will emerge the inefficient cognitive process. Regarding the germane cognitive load, this cognitive process will occur automatically if there is an empty load in the working memory due to minimum intrinsic and extraneous cognitive loads and this process is possible to be influenced by motivation and attitude of learners towards the studied material [13].

3. Method
This research was a qualitative descriptive research. The descriptive research was used because the objective of this research is to describe the cognitive loads of learners in the learning process of integral especially about the rotating object volume. The 3 (three) learners from XII grade are the subjects. The purposive sampling technique was used to determine the research subject. The learners who determined as subjects are consist of learners with high mathematics skill (A), moderate mathematics skill (B), and low mathematics skill (C) which conducted in accordance with results of consultation with the mathematics teacher in the related class. This activity is conducted to acquire a complex description associated with the studied problems.

The data colleting methods used are test and interview. Test was used to see in written context regarding the work results of learners in determining the rotating object volume through an integral as well as to seek for the errors that might occur. Meanwhile the semi-structured interview was used to confirm the written answer of learners. This activity was used to acquire more specific description regarding the issues faced by learners associated with the learning process in this material.

4. Results
In order to see the intrinsic cognitive load of learners in determining the rotating object volume through the use of integral, the author has proposed question in the form of essay to be answered in the written form by the selected three subjects. The question given is “Please calculate the rotating object volume if the area limited by curves of $y = -x^2 + 4$ and $y = -2x + 4$ is rotated by 360° around the Y axis”. From the three learners who given the test, only one learner was attempting to solve the question (student A). The student work can be seen in figure 1.

![Figure 1: The Answer of Learner-A](image)

For the provided question, the Learner-A is answering by finding the limits on X axis which performed through an equation method by using the two provided equations/formulations. After the limits are discovered, a formulation is used to find the square in attempt to determine the rotating object volume, while the Learner - B and Learner - C did not write the answer. According to the answer of Learner – A towards the problem given, it is known that the learner is having an early error that quite fatal; which is the error in extracting the important information of the question. The learner is solving the problem with a principle that the area is rotated around the X axis, while the instruction in the question is rotated towards Y axis. The second error conducted by the Learner – A is calculating the volume or rotating object by using the square equation.

The next phase is the author that conducts interviews towards the three learners regarding the work results which are done by them. The results are as follows.
Learner A
P: What is your idea to solve it?
A: Because the limits are not yet available in there, so I find the xx values. I equate the function until the values of $x_1$ and $x_2$ are found.

P: In attempt to find the $x$, it means that it has to be rotated towards the X axis right? Pay attention to my figure. (The learner is looking closely at the author’s figure)
Due to its rotation towards the y axis, it means that the limits towards the Y axis are have to be found, so the \( y_1 \) and \( y_2 \) that should be done right? Can you determine it?

A: *Its confusing sir.*

P: Did the teacher explain this question to you?

A: *He did, I just did not understand it thoroughly.*

P: Why did not you ask?

A: *I feel ashamed to do it.*

P: Do you study later at home when you have not understand it yet?

A: *No sir (while laughing)*

P: In order to solve this problem, the method is almost similar with yours, the difference is that the \( f(y) \) function which has to be equated. Pay attention to how I do it, then you finish it.

*The learners are paying attention and continuing the process until the values of limits on the y axis are acquired*

P: Why did you measure volume by using the square formulation?

A: *I forgot the formulation at that time sir.*

**Learner B**

P: Why did not you do it?

B: *It’s difficult sir, I did not know how to do it.*

P: Have you ever been taught the method to measure the rotating object volume with an integral?

B: *I have, but it’s not clear for me.*

P: How was the teacher taught you before?

B: The teacher wrote equations on the board, then gave questions as the examples, but I did not understand what they were.

P: Why didn’t you ask the teacher if it’s not clear for you yet?

B: *I feel ashamed sir.*

P: You didn’t ask your friend?

B: *No sir.*

P: Why?

B: Just lazy to do it.

P: In which part did you find the difficulty?

B: *How does it looks like if being rotated in 360 degrees, sir?*

*The learner is solving the question with the help of the author, however, its clearly seen that the learner is having difficulties in determining the limits and including them into the equation*

**Learner C**

P: Why didn’t you do it?

C: *I already forgot about it.*

P: I will remain you if you forgot (the author writes down the equation on the paper). Can you use this to solve the question?

P: *I still feel confuse sir*

*The learner is solving the question with the help of the author, however, its clearly seen that the learner is having difficulties in changing the \( y \) function into the \( x \) function, determining the limits, and including them into the equation until the process of calculating the results)*

According to the interview results, it is known that the Learner A is still having a difficulty in understanding the concept of rotating object volume if it’s being rotated towards the Y axis. According to this result as well, it is known that the Learner A has not been able to properly use his analogical ability, due to that matter, he only understands the rotation towards X axis. The incomprehension of Learner A is already happened since the beginning, it means that since this material was provided in the class, the learner has not properly understood this material. According to the interview results, it is also known that the motivation of learner in studying this material is quite low. Although the learner has not properly comprehended this material, however, the motivation to improve his understanding is quite low. This condition can be seen from the low motivation of learner to study the material in further at home, he did not even attempt to ask the teacher. The interview results also show that the
Learner A tends to memorize the equation which results in Learner A forgetting the equation for rotating object volume. This situation that causes the learner to use the square equation to measure the volume on the given question.

The Learner B has been discovered to have a difficulty in comprehending the method to determine the rotating object volume by using an integral. Although the equation has been provided, however, the Learner B is still having a difficulty in using the equation to determine the rotating object volume. This condition is also occurred on the Learner C in which this subject is totally did not understand the meaning of the question and how to solve it. According to the information acquired from Learner B, it is also known that this learner is having difficulty in imagining an area limited by two curves which rotated around the Y axis. By referring to the information provided by the learners regarding the learning process in a class, it is known that the teacher has taught this material in a conventional way in which the teacher wrote down the equation on the board then giving some examples. The teacher has not provided the geometric illustration of the rotating object concept, thus, the learners are not able to imagine the form of the object if it’s being rotated towards a certain axis. The intention of learners towards the comprehension of this materialist also seems low, the learners’ understanding towards this material is low, however, they have no attempts to properly master the material.

The Learner C has been discovered to did not completely understand the material including the algebra computation. The Learner C is having no comprehension since the beginning about the concept and rule of an integration, even the materials which should be mastered in prior as the required knowledge are still not properly understood. The skills in arithmetic and algebra are low as well. These conditions which cause the learners to have difficulties in solving the given problem, from understanding the problem to the attempt of solving it.

5. Discussion
As what presented in the literature review in which the cognitive load theory divides the cognitive load into three types, namely intrinsic cognitive load, extraneous cognitive load, and germane cognitive load. The intrinsic cognitive load which emerged in the learning process of a rotating object volume is caused by the difficulty of learners in imagining an area which limited by two curves which rotated 360° around the Y axis. This difficulty in imagining the area which made the learners to being unable in configuring the form of the rotated object that later results in the failure of understanding the given principles. This condition is parallel to the argument of [14] who mentioned that the difficulty in the imagining process has made the learners to be less capable in configuring a perspective, the recognition of form and position as well as the representation of a perspective. Another difficulty that causes the occurrence of intrinsic cognitive load is the learners’ difficulty in analogizing a case with another case. There are students who already comprehend the rule in determining the rotating object volume if being rotated towards X axis, however, they unable to solve the question if the instruction is the rotation towards Y axis. This low analogical capability that causes the students to find difficulties in solving the given problem. The low competency of students in the supporting materials also made some students to find difficulties in properly understanding the material. The low competency of students in the supporting materials also made them to find difficulties in properly understand this material. The low competency on the required materials such as arithmetic, algebra, concept, and rule of integrating is also becoming the inducing element of the occurrence of an intrinsic cognitive load. The capability of learners in performing the operations of algebra, arithmetic, concept, and rule of integrating is an intrinsic cognitive load because these elements have been studied in prior and associated with the element that being studied at present [7].

The extraneous cognitive load in the learning process of this material can be seen from the condition or situation correlated to the learning design. The extraneous cognitive load is the load that comes from the instructional design which makes the learners to be more burdened [6,7]. The extraneous cognitive load in the learning process in a rotating object volume is caused by the way of teacher presenting the ambiguous and meaningless materials. What have been delivered by teacher are unable to be properly understood by learners. By looking at the condition of Learner A who able to solve the problem even after already receiving the explanation from the author has shown that this learner is actually having decent competency, however, because he has not been completely understand the material in the class, thus, he unable to solve the given question.

Teacher wrote down the equation and gave examples without accompanied by clear narrations that cause the learners to have no understanding since the beginning. The teacher did not form a geometric illustration regarding the material that also cause the learners to being unable to imagine the rotating object. According to the interview results, it has been known as well that the teacher has not been implementing a meaningful learning. This condition has caused the learners to easily forget the materials given by teacher. The meaningful learning itself has become important in the mathematics learning, especially on this material. This argument is in
line with the opinion of [15] who explained that the learners have to receive a meaningful learning, thus, they would have more understanding towards the taught materials.

Germane cognitive load in the learning process of rotating object volume material is the relevant effort of learners in understanding this material. On the other words, a germane cognitive load is coming from the mental effort spent by learners to understand the material. It has been known that the germane cognitive load in the learning process of this material is quite low, even it can be said that the germane cognitive load has not been occurred in the learning process. The learners tend to be passive in the learning process. The learners are shy and lazy to ask, they also have no intention to learn the material in further by themselves, this condition has caused the learners to having more difficulties in creating analogies on this learning.

According to the interview results, it is also known that teacher has not been implementing an effective learning process, such as the learning that could emerges or improves a germane cognitive load. As a result, the information that being processed by learners is ineffective. The teacher should minimize the intrinsic cognitive load to gain implications on the increasing level of the germane cognitive load. This argument is similar to the opinion expressed by [5] who mentioned that the suitable processing activity of an intrinsic cognitive load will have impacts on the increasing germane cognitive load in the learning process.

6. Conclusion
The intrinsic cognitive load in the learning process of the rotating object volume occurs due to the amount of interactivity elements that has to be learned and the complexity of material that being studied. The intrinsic cognitive load which caused by the amount of interactivity elements is the amount of material topics that has to be studied in a specific material. The elements which interacting in the learning process of a rotating object volume are arithmetic, algebra, the cutting point of two curves, concept and rule of integrating. Meanwhile the intrinsic cognitive load that caused by the complexity of material is the difficulty in imagining the rotating object and the difficulty in performing the operations of algebra and arithmetic.

The extraneous cognitive load in the learning process of the material of the rotating object volume is occurred due to the learning design that makes the learners to find more difficulties in understanding the material. The occurrence of an extraneous cognitive load in the learning process of rotating object volume is caused by the way teacher delivering meaningless materials, thus, the learners did not understand the things delivered by the teacher. The absence of geometric illustration from the teaching conducted by teacher is also caused the students to have difficulties in imagining the visualization of the rotating object form.

Regarding the germane cognitive load in the learning process of rotating object volume material, it has been known that this cognitive load is quite low. The low level of germane cognitive load is caused by the learning process in class which more in a conventional way as well as the lack of learner’s activities in studying the material. As an alternative solution in managing the intrinsic cognitive load, reducing the extraneous cognitive load, and improving the germane cognitive load, the teacher is able to use Win plot software in the learning process to facilitate the learners in the process of imagining as well as to provide them with exercises with varied questions.

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