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Student Extraneous Load Analysis in Online-Based Plant Tissue Structure Learning

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Abstract: This study aims to determine the cognitive load of students in online-based plant anatomy learning. The research was conducted at the Biology Education Study Program at a State University in Palembang, Indonesia. The research subjects were Biology Education students (n=73) who contracted the plant anatomy course. The instrument used to determine students' mental effort in understanding plant anatomy material is a questionnaire with a Likert scale with five answer choices: very easy (VE), easy (E), moderate (Md), difficult (D), and very difficult (VD). The aspects measured are (i) identifying the type of tissues and its characteristics by observing 2D and 3D images; (ii) analyzing the interrelationship of tissues structure and it function; (iii) identifying the structure of the constituent tissues in several plant organs, and (iv) spatial thinking related to the structure of plant tissues. The research data shows that the highest percentage in all aspects is in the medium category (MD), which ranges between (31.14% - 47.69%), which means that the learning carried out is not too burdensome for students in these four aspects. However, the data also shows that in the second aspect, namely the ability to analyze the relationship between structure and function, 31.64% of students stated that it was difficult. This is due to the complexity of the material related to the structure and function and the ineffectiveness of the media used in online-based learning.

Keywords: Cognitive load; Mental effort; 3D picture; Plant tissue

Introduction

Today, all level educational activities cannot be separated from the use of technology. The demands of this era and the challenges of education in the 21st century have made most of the learning process shift from offline to online (Lee et al., 2015).

The demands of the times and the challenges of education in the 21st century as well as the conditions of the pandemic, require learning to be carried out not always limited by space and time. The learning can be done anytime, anywhere, and in an unlimited time dimension and is predicted to have lower costs (Papadakis et al., 2018; Rawashdeh et al., 2021).

In addition, the pressure of the global Corona Virus Disease (COVID-19) pandemic has affected the education system in the world, including Indonesia. The condition of the Corona Virus Disease (COVID-19) pandemic which forces all educational institutions to carry out distance learning. This refers to Ministerial Decree n umber 01/KB/2020 June 15, 2020 regarding guidelines for the implementation of learning in the 2020/2021 Academic Year and the 2020/2021 Academic Year during the COVID-19 pandemic period.

Based on the several previous research Dalgaly (2020), Costley (2019), Rawashdeh (2021), and Wu et al. (2022) it can be concluded that online learning provides many benefits including: (i) Online learning provides greater opportunities for students to access information from various sources compared to traditional learning; (ii) The learning process can be done anytime and anywhere. (iii) More economical for student who use it. Various research results show that online learning with various learning methods can improve student learning outcomes. Research also shows that students will learn better online compared to offline (Costley, 2019). This

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also makes learning based Web is one of the best choices for all levels of education, both synchronously and asynchronously.

However, it cannot be denied that the use of high technology in the learning process does not necessarily improve student learning outcomes. This is supported by the previous research which shows that online learning will not always benefit students, even in some situations it will be confusing for students (Dalgaly, 2020; Lange et al., 2017; Rawashdeh et al., 2021), thereby increasing cognitive load (Broadbent et al., 2015; Hun et al., 2020; Lange et al., 2017; Skulmowski & Xu, 2021).

Furthermore Lange et al. (2017), states that in online learning, the material and instructions must be delivered clearly so that student motivation and involvement is maintained. Inappropriate instructions and other unsupportive content can be one of the causes of decreased student performance and engagement in online learning (Lange et al., 2017, 2018). Furthermore Skulmowski et al. (2021), states that in online-based learning it is very necessary to consider the positive or negative impacts of a developed learning design.

From several previous studies, it can be seen that online learning, by using various applications, sometimes often causes irrelevant cognitive loads (Brom et al., 2018; Skulmowski et al., 2018; Skulmowski & Rey, 2021). Therefore, it is very important for an educator to find out whether the online learning process that has been carried out is able to increase student motivation and involvement or actually causes other cognitive burdens. Educators really need to use various technologies in minimizing the extraneous load that arises in the learning process. Based on several sources, it is known that cognitive load is related to working memory theory, where various forms of cognitive load can fill the working memory (Lange et al., 2017; Skulmowski & Xu, 2021).

The results of studies related to cognitive load show that cognitive load greatly affects student learning outcomes. This refers to the cognitive load theory of cognitive load which states that the information processing load induced by learning tasks can affect students' ability to process new information to build knowledge in long-term memory (Sweller et al., 2019). Cognitive load consists of three components, namely Intrinsic Load (ICL), Extraneous Load (ECL), and Germane Load (GCL) (Lange et al., 2017; Skulmowski & Xu, 2021; Sweller et al., 2019). Intrinsic load is related to the complexity of the material presented (Shadiev et al., 2015). Extraneous Load relates to an inappropriate type of instruction, where an unneeded amount of information is provided, for example the way the material is presented (Sweller et al., 2011), which requires students to be able to process the information (Leppink et al., 2013; Schmeck et al., 2015). Germane Load is related to students' efforts in processing cognitive information to build understanding of learning materials (Kolfschoten et al., 2010; Sweller et al., 1998).

The result of the research related to cognitive load shows that cognitive load is strongly related with working memory. Working memory is a temporary storage to keep information received from the environment (Isik et al., 2017; Thornton, 2018). Working memory has limitations in receiving and saving memory (Adams et al., 2018; Li et al., 2023; Sweller et al., 2019). Working memory will overload if unnecessary, unimportant, too much or simultaneously information enters the cognitive system. This is the first factor that can affect the learning effectiveness and the information transferring. Some situations that cause the increasing of the cognitive load include the complex environmental conditions that demand a lot of performance and tasks, inappropriate instructional methods and other distractions from the learning environment (Sweller et al., 2019). The management of cognitive load can be done by minimizing irrelevant things and optimizing the relevant things in learning (Paas et al., 2020).

Based on cognitive load theory, the use of short-term memory can optimize if the teacher in learning can decrease the amount of extraneous load, manage the intrinsic load becoming parts that can easily captured by students, and encourage the increasing of the Germane load (Jordan et al., 2019; Lange et al., 2017).

Furthermore, it is said that many factors affect the information processing when a person do a certain task, including: material complexity, poor instructional delivery, less than ideal learning environment (Lange et al., 2017) or imprecise digital learning design (Skulmowski & Xu, 2021), so it is very important for the management of cognitive load in learning, especially online learning. Unnecessary cognitive load, can be removed or reduced by optimizing the learning design (Sweller et al., 2019). The assumption is when the distraction is removed, the student's working memory will have more capacity to save the information in order to forward it to long-term memory. This is because students will focus more on the presented learning information. This causes many attempts did by educators so that the presented learning can be appropriate with the goals to be achieved.

The same thing was also done in plant anatomy lecture that conducted at a State University in South Sumatra. Although analysis related to online learning is very frequently done from various levels of education and subjects but the research related to how the impact of online learning on the student's cognitive load especially related to extraneous load in plant anatomy course has never been done. Thus, it is important to analyse the process of implementation online-based plant anatomy lecture.

The Plant Anatomy course is a course that demands the student to understand plant tissue structures which are microscopic and relate it to functions (Ermayanti et al., 2017; Ermayanti et al., 2018). Previous research relate to plant anatomy learning has also shown that student's reasoning ability, logical thinking and special thinking related to plant anatomy can be increased by framing-based learning (Ermayanti et al., 2016; Ermayanti et al., 2017). However, from all research data and literature review, shows that there is no information about how the student's cognitive load on plant anatomy online-based learning. Moreover, the condition of Covid-19 pandemic that cause plant anatomy learning that did last two years did not held the practicum activity in laboratory.

Plant anatomy learning is only held by using visual media containing narration, two-dimensional pictures (2D) and three-dimensional pictures (3D). It is held by referring to previous research which said that learning plant anatomy is closely related to representation with words, pictures or videos both in online and offline learning (Ermayanti et al., 2018; Susiyawati et al., 2021).

Learnings by words and pictures or video are the example of learning that can be held in online and offline. However, the current question is how is the student's mental effort to understand the characteristic of the tissue structure, the relation of the structure and the function of plant tissue and spatial thinking, by online-based learning strategy that are applied? This research is important to do to find out whether visual media used in online learning so far can facilitate students in understanding the characteristics of the structure and the function of plant tissue and spatial thinking. This research is expected can be used as the basic information in developing the process of the further plant anatomy learning especially in online-based.

Method

This research is a descriptive study that aims to explain how the cognitive load exactly extraneous load of the student in online-based plant anatomy learning. The subjects were Biology Education students (n=73) which consist of two classes that take Plant Anatomy course. This research was conducted at Biology Education Study Program in Sriwijaya University. This research was held on in the even semester of 2020/2021. The subjects are the second semester students (n=73), who took the online plant anatomy course. Online plant anatomy learning was held using visual media such a PowerPoint slideshows containing narration, 2D pictures, and also 3D pictures that are given to students both synchronously and asynchronously.

The parameter measured is Extraneous Load (ECL). Extraneous load measurement is held using a linkert scale questionnaire instrument with five options, such as Very Easy (VE), Easy (E), Medium (Md), Difficult (D), and Very Difficult (VD). The thing that wants to be known is how the student's effort in understanding the relation of the structure and the function of the plant tissue and the ability of spatial thinking by applying online learning strategy. The four aspects of mental effort measured are related to (i) identifying the type of the tissue and its characteristics by observing the 2D and 3D pictures; (ii) analysing the relation of the structures and the functions; (iii) identifying the structure of constituent tissues in some plant organs; and (iv) spatial thinking about anatomy plant structure.

The research data is a student's Extraneous Load (ECL) which is analysed by counting the percentage of achievement in each indicator. The higher the student's difficulty level in understanding every measured aspect, it is higher the Extraneous Load (ECL).

Result and Discussion

The student's cognitive load in the learning of plant anatomy is observed by measuring the Extraneous Cognitive Load (ECL). The measurement of student's ECL is held by observing four mental effort aspects such as (i) identifying the type of the tissue and its characteristics by observing the 2D and 3D pictures; (ii) analysing the relation of the structures and the functions; (iii) identifying the structure of constituent tissues in some plant organs; and (iv) spatial thinking about anatomy plant structure. It is assumed that the higher the student's difficulty level in understanding every measured aspect, it is higher the Extraneous Load (ECL).

The results showed that the highest ECL percentage in all aspects was in the moderate category (Md), which means that the average student (31.14%- 47.69%), stated that the learning held did not burden students too much on these four aspects (Table 1). However, the data in Table 1 also shows that in the second aspect, namely the ability to analyse the relation between structure and function, the percentage of students who stated difficult (D) was 31.64% and students who stated it was very difficult, namely 5.90%. This is different from the other three aspects which have a percentage below 20% in the Difficult (D) category. The data in Table 1 also stated that in the aspect of analysing the interrelationships of structure and function, the percentage of students who stated that it was very easy was only 0.27%. So it can be concluded that in analysing the relationship between structure and function, students have a more burden when compared to the other three aspects.

Table 1. The Percentage of Student's Extraneous Load in Online-Based Plant Anatomy Learning

Aspects	Descriptions				
	VE	E	MD	D	VD
Identifying the type of the tissue and its characteristics by observing the 2D and 3D pictures	8.35	35.82	37.14	18.68	0.00
Analysing the relation of the structures and the functions	0.27	21.18	41.02	31.64	5.90
Identifying the structure of constituent tissues in some plant organs	3.54	30.77	47.69	16.00	2.00
Spatial thinking about anatomy plant structure	7.35	33.68	37.26	17.95	3.76

Based on data analyse in Table 1, shown that the hardest aspect in student is the aspect of analysing the relation of structure and function. It means, although generally learning process using slideshow is able to facilitate the student in analysing the relation of structures and functions but there are still some students that feel the difficulty to understand namely 31.64% (D) dan 5.90% (VD). The student's difficulty in analysing the relation of structures and functions because this learning demands the students to think more details about the structure of the tissue and analyse its function. According to Ermayanti et al. (2017), in understanding the structure and the function, students must be able to analyse the structure (e.g shape, size, position and other characteristics and relate it to the functions). To understand the structure's representation in 3D, requires the complex thinking process. Students must save information about its shape, color, and the tissue position either in cross section, longitudinal or radial cross section (Ermayanti et al., 2017). Based on study in several sources, it can be concluded that the more complex a material is, the bigger the cognitive load a person has in understanding it (Kalyuga, 2011; Lin et al., 2014; Moreno et al., 2010; Pertiwi, 2020; Sweller et al., 2019), Nevertheless, if a complex material can be arranged as well as, it will decrease the student's cognitive load in understanding it (Gunarsih, 2018).

Based on cognitive load theory, there are three components in cognitive load, such as, *intrinsic cognitive load* (ICL), *extraneous cognitive load* (ECL), dan *germane cognitive load* (GCL) (Kalyuga, 2010). ICL is related to cognitive load in information processing that received from environment. The more complex the information processed is, the higher ICL is. While, ECL is cognitive load that appear as the result of the improper instructional methods (Kalyuga, 2010), the learning design or the bad material organization, while, GCL is a cognitive load that appear as a effort to understand or possess the material (Sweller, 2005; Sweller, 2010).

Based on the findings in the field, it is known that the use of media or strategies used in online plant anatomy learning that has been carried out needs to be reviewed. This is in accordance with the theory which states that students' understanding of a material is highly dependent on the media and learning strategies used. Skulmowski et al. (2021) stated that to increase the cognitive effectivity in receiving the information, it needs to decrease the ECL. Moreover, Brom et al. (2018) stated that multimedia-based learning must attend the cognitive learning principles multimedia-based. Diemand-Yauman et al. (2011), said that the using of appro200priate letters, can cause the distractions in the learning materials. Even, the excessive ornate elements can cause distractions in the learning process (Brom et al., 2018). On the other hand, the using of soft colors, can cause the positive response that enhance the learning (Brom et al., 2018).

Based on material analysis, the plant anatomy course contains the studies about cell structure, tissue and microscopic plant organ but having 3D structure (Ermayanti et al., 2017; Ermayanti et al., 2018), so to understand the structure's characteristic and relate it to its function needs the high mental effort. The assumption is that the greater the student's mental effort in understanding the structure of plant tissue, the higher the ECL. According to Sweller (2010), ECL can appear because of several things like the complexity of teaching materials, environment or the using of learning strategy.

Based on the analysing of plant anatomy learning process, known that learning process using slideshow media containing 2D and 3D pictures can help students in understanding the tissue structure or plant organs. However, the result of analysis and personal communication about learning condition shows that visual-based learning strategy like 2D and 3D pictures is not very effective in delivering plant tissue structure learning. This is because the slides are too many, because the students is having the difficulty to remember the characteristic of structure and function given. In addition, the quality of the internet network, which is sometimes unstable, causes students to lose verbal information conveyed by the lecturer when presenting *slides*, while students find it difficult to repeat independently. All these things lead to an increase in the cognitive load of students and the processing of information in working memory is hampered.

Conclusion

The research data shows that the highest percentage in all aspects is in the medium category (MD), which ranges between (31.14-47.69)%, which means that the learning carried out is not too burdensome for students in these four aspects. However, the data also shows that in the second aspect, namely the ability to analyze the relationship between structure and function, 31.64% of students stated that it was difficult. This is due to the complexity of the material related to structure and function and the ineffectiveness of the media used in online-based learning.

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Author Contributions
Ermayanti, Rahmi Susanti and Lucia Maria Santoso devised this research, the main conceptual ideas, carried out the experiment and analysis data. Ermayanti conducted literature review and wrote the manuscript with support from Chelsie Novalin Deluciana. Authors contributed to the final version of the manuscript.

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Conflicts of Interest
The funder had no role in the design, data collection, and analysis of this research. The authors were agreed with this manuscript.

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