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The Rasch Analysis of Students' Characteristics in Physics Concept Understanding Improvement through Challenge-Based Learning

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Abstract

Concept mastery is one of the main goals in the learning process. This study aimed to analyze the improvement of students' physics concept mastery by implementing challenge-based learning with Edmodo-assisted learning. This study used mixed methods with an embedded experimental model research design. The research sample was 10th-grade students in a public vocational school's food crops and horticulture agribusiness program. Data analysis employed the Rasch model with the help of ministeps software version 4.1.1. The results of this study indicate a significant increase in students' conceptual mastery of +3.44 logit. The average logit value of students' abilities is higher than the average logit value of the item difficulty level. Students' physics concept mastery can be improved through the challenge-based learning model assisted by Edmodo.

Keywords: concept mastery, challenge-based learning, Rasch analysis

INTRODUCTION

Concept mastery is essential and cannot be separated from the learning objectives. Concept mastery is the ability of students to understand learning and apply it in their lives (Ibrahim, Rochintaniawati and Sanjaya 2017). Concept mastery can improve students' intellectual abilities, help them solve problems, and give them meaning in learning (Anderson et al. 2001). Research on enhancing students' physics concept mastery is essential to conduct. Many studies on physics concept mastery have been undertaken using learning models and approaches. Several previous studies showed that predict-observe-explain (POE) learning strategies (Furqani, Feranie and Winarno 2018), argument-driven inquiry (Salsabila et al. 2019), three-dimensional solid object motion mechanics (Hartini et al. 2020), and guided inquiry-based practical manual (Andriani, Sunyono and Abdurrahman 2018) effectively improve students' concept mastery. Good concept mastery is also influenced by authentic assessment learning models. It approaches through project-based learning (Andanawarih, Diana and Amprasto 2019), STEAM (Wandari, Wijaya and Agustin 2018), multiple intelligence-based learning (Pratiwi, Rochintaniawati and Agustin 2018), and Brain-Based Learning (Sani, Rochintaniawati and Winarno 2019). In this study, the authors conducted research using a challenge-based learning (CBL) model to investigate the improvement of students' physics concept mastery.

Challenge-based learning (CBL) is a learning model in which teachers and students work on projects to find solutions to a challenge (Johnson et al. 2009). Challenge-based learning is collaborative learning based on learning experiences. Students and teachers work together to learn from exciting problems around their environment, propose solutions to these problems, and take action (Apple Education 2010). Challenge-based learning is also a multidisciplinary approach to education that encourages students to utilize technology in solving real-world problems (Johnson and Adams 2011). CBL learning application uses ten syntaxes: big ideas, essential questions, the challenges, guiding questions, guiding activities, guiding resources, solutions, assessment, publishing, and reflection (Johnson et al. 2009). Implementing CBL can help students become active and master the subject matter (Johnson and Adams 2011) and increase student creativity (Yang et al. 2018). Research on CBL is also evolving with various forms of technology (Marin, Hargis and Cavanaugh 2013; Yoosomboon and Wannapiroon 2015). The use of specific learning media can support the use of learning models. In this study, the implementation of CBL learning was carried out with the help of Edmodo learning technology to improve students' mastery of physics concepts. Teachers can use the Edmodo platform as the primary means of information sources, simulation media, videos, teaching materials, assignments, and evaluations (Chao, Parker and Fontana 2011; Trust 2012; Kongcsshan 2013). Edmodo has been widely used in the learning model to increase student activity, cognitive, motivation and critical thinking skills (Joko and Wulandari 2018; Baharun et al. 2019; Fathimah, Wulan and Solihat 2019; Denny et al. 2020).

The development of a Learning management system (NGO) using Edmodo resulted in higher differences in learning outcomes in cognitive, affective, and psychomotor aspects than direct learning models (Joko and Wulandari 2018). Based on several findings in previous studies, the use of Edmodo is thought to help optimize CBL as a learning model that teachers can use to improve students' concept mastery. Edmodo is essential in the extensive idea section, guiding resources and publishing to train students to find information in solving challenges. Students' concept mastery can be improved based on students' experience in solving challenges. In previous studies, the improvement in concept mastery was analyzed through the value of N-gain (Andriani, Sunyono and Abdurrahman 2018; Furqani, Feranie and Winarno 2018; Pratiwi, Rochintaniawati and Agustin 2018; Wandari, Wijaya and Agustin, 2018; Andanawarih, Diana and Amprasto 2019; Salsabila et al. 2019; Sani, Rochintaniawati and Winarno 2019). The progress in concept mastery was also analyzed using ANOVA test (Satriawan, Liliasari and Setiawan 2019; Amalia et al. 2020) and t-test (Setiawan, Sopandi and Hartati 2020). In this study, the author will explore the characteristics of increasing students' physics concept mastery using the Rasch model.

Rasch modeling can be used to measure assessment test items in learning (Sumintono 2018). In this study, Rasch modeling was used to analyze the characteristics of increasing students' mastery of physics concepts and students' cognitive level achievements. Physics concept mastery that will be analyzed in this study is the topic of Hydrostatic Pressure in the food crops and horticulture agribusiness program at Vocational High Schools. Hydrostatic pressure topics that will be studied include the relationship of physical quantities such as fluid density (ρ), gravitational force (g), and the depth of a fluid (h). This physical quantity relationship can be expressed through the equation:

$$P_h = \rho \, . \, g. \, h \tag{1}$$

EQUATION 1 is a fundamental concept of hydrostatic pressure. Several previous studies analyzed students' conceptual mastery based on the revised edition of Bloom's taxonomy (Vania, Setiawan and Wijaya 2018) at cognitive levels C2 - C4 (Saprudin, Liliasari and Prihatmanto 2017), C1 - C3 (Furqani, Feranie and Winarno 2018; Yalçın and Şevik 2019), C1 - C4 (Sani, Rochintaniawati and Winarno 2019; Amalia et al. 2020), and C4 - C6 (Wicaksono, Wasis and Madlazim 2017; Wandari, Wijaya and Agustin 2018; Salsabila et al. 2019). In this study, the author will analyze the characteristics of students' mastery of physics concepts at cognitive levels C1 to C6 according to Bloom's Taxonomy (Vania, Setiawan and Wijaya 2018). The measurement of concept mastery was carried out on three question themes, namely the theme of dams in agriculture (Theme A), solving the challenges of purity of pertalite (theme B), and hydrostatic pressure on lake and seawater (theme C). Thus, this study aimed to analyze the characteristics of students' mastery of physics concepts through the challenge-based learning (CBL) learning model assisted by Edmodo. This characteristic analysis includes increasing students' concept mastery and analyzing student achievement at each cognitive level: remembering, understanding, applying, analyzing, evaluating and creating (C1-C6).

METHODS

This research uses mixed methods with the research model design using the embedded experimental model. The stages of the study can be seen in FIGURE 1 below.

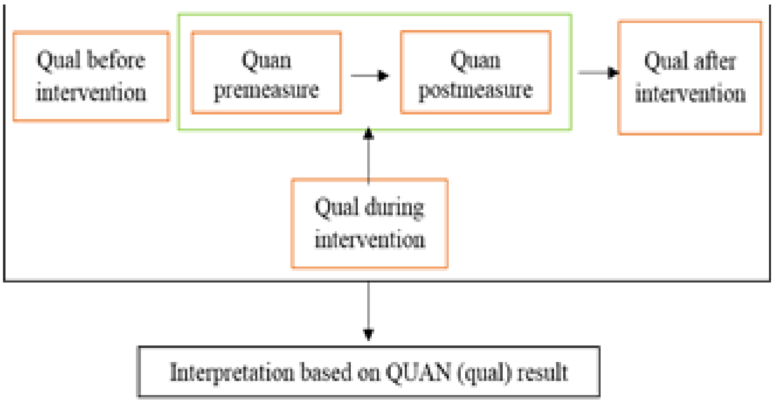

FIGURE 1. The embedded experimental model design.

FIGURE 1 shows the design flow of the research stages with the embedded experimental model. This qualitative data was collected from interviews with teachers and students, analysis of core competence and basic competence, and lesson plans used in learning. Other qualitative data is in the form of a literature study on the findings of previous research that are relevant to the problem to be solved. Qualitative data were obtained to complement the quantitative data during the intervention process on the research object. Quantitative data were obtained by giving a pretest and post-test. After the intervention and quantitative data collection through the post-test, qualitative data collection was still conducted through interviews related to the dependent variable. Then, based on the processing of quantitative and qualitative data, the interpretation of the data is obtained, which becomes the result of research and conclusion.

Jeki is a vocational student majoring in food crops and horticulture agribusiness in a school. This major is synonymous with subjects related to agricultural knowledge and activities. One aspect that supports the continuity of agricultural activities is the water source from the dam building

***source**: https:www.google.com/bendungan*

1. Write down the physical quantities associated with the pressure on the dam!

2. In every dam construction, the bottom wall of the dam is always made thicker than the top. Explain why this should be done!

3. If the dam is 25 meters below the water surface, what is the water pressure at the bottom of the dam?

FIGURE 2. Sample test questions.

The sample of this study was taken at one of the public vocational schools in the food crops and horticulture agribusiness program in Bungo Regency, Jambi Province, Indonesia. The sample of this study amounted to 26 students consisting of five male students and 21 female students. This sample consisted of various ages, namely six students aged 17 years, 12 students aged 16 years, and eight students aged 15 years. This sample has different cultural backgrounds and social circumstances. Some come from the local indigenous population (Jambi Malays) and immigrants from the Javanese, Batak, and Minangkabau tribes.

This study used several instruments to obtain quantitative data and qualitative data. The instrument used to collect quantitative data was a test instrument consisting of 18 questions, while an interview sheet was used to collect qualitative data. The test instrument was arranged based on Bloom's Taxonomy to evaluate students' concept mastery, starting from the cognitive level C1 to C6.

Each cognitive level consists of three question themes, namely about water dams for agriculture (theme A), proving the purity of pertalite (theme B), and hydrostatic pressure on lake and seawater (theme C). Five validators have validated this instrument: four lecturers and one physics teacher. The results of these measurements were analyzed using the Many-Facets Rasch Model. The data from this study were analyzed using the Rasch model with the help of the ministeps software version 4.1.1 to see the characteristics of increasing the logit value of students' mastery of concepts.

RESULTS AND DISCUSSION

Characteristics of students' concept mastery

The data characteristics of the quality of students' concept mastery of the hydrostatic pressure material were obtained through pretest and post-test activities. The data from the pretest and post-test activities were used to answer the formulation of the research problem, namely knowing the characteristics of increasing conceptual mastery of SMK students after receiving Edmodo-assisted CBL learning. Changes in the data from the pretest and post-test results were used as data to increase students' concept mastery. Student data reports (person) are written with student codes in the form of numbers (1-26), gender male (L)/female (P), and student demographics, in general, are students who live in villages but consist of various ethnic groups, namely ethnic groups Malay (M), Javanese (J) and Batak (B). Writing the student code aims to assist the author in finding out and getting to know more precisely the state of the research sample. More specifically, efforts to identify students' characteristics are expected to complement student data in increasing students' mastery of concepts. The data on improving students' concept mastery can be seen in the mean values of the pretest and post-test results. Data analysis was carried out using the Rasch model in logit units. Data on increasing students' mastery of concepts can be seen in TABLE 1.

TABLE 1. Pretest and post-test data of students' concept mastery

Pretest	Measure	Posttest	Measure	Improvement	Measure
Mean	- 1.53	Mean	1.91	Mean	3.44
Standard deviation	. 68	Standard deviation	2.16		

TABLE 1 shows the mean values for the pretest and post-test results, namely -1.53 logits and 1.91 logits, respectively. The increase in the mean value on the pretest and post-test was + 3.44 logits. These results indicate that the increase in students' mastery of physics concepts on the hydrostatic pressure material using the Edmodo-assisted CBL learning model occurs significantly (> +1 logit). Furthermore, there is a significant difference in standard deviation on the pretest and post-test, namely 0.68 and 2.16. The standard deviation value on the pretest, which is close to 0.5 logit can be interpreted that the distribution of the concept mastery ability of all students on the hydrostatic pressure material is approximately the same. Meanwhile, the post-test standard deviation value, greater than 1 logit, indicates that the distribution of students' concept mastery in the post-test results is more spread out and not the same. This data analysis provides information that the challenge-based learning model assisted by Edmodo can affect increasing students' concept mastery. The characteristics of students' concept mastery become more varied and spread at specific logit values.

Knowing the distribution grouping of students' concept mastery achievement becomes important in understanding the characteristics of increasing students' conceptual mastery. In knowing the distribution of data on the increase in students' conceptual mastery, we can use the mean and standard deviation values to determine the distribution of groups for increasing students' conceptual mastery. The mean value of 1.91 logits is added up with a value of 1 standard deviation (2.16 logits) so that the value of +4.07 logits is obtained as a group of +1 SD. Then the +4.07 logits value is added with a value of 1 standard deviation again 2.16 logits so that the +6.23 logits value is obtained as a +2 SD group. If a student's concept mastery logit value exceeds 2 SD (> +6.23 logits), then the student is included in the outlier group. On the other hand, to determine the two groups below the mean, we subtract the mean value of 1.91 logits by the standard deviation of 2.16 logits and obtain a value of -0.25 logit as a group of -1 SD. Then the value of -0.25 logit is reduced by the standard deviation of 2.16 logit, and the value of -2.41 logit is obtained as a group of -2 SD. If the students' ability is less than -2.41 logits, the student is included in the outlier group. Information on the distribution of students' concept mastery can be seen in FIGURE 3.

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
			very high										
14	68	18	6.18	.72	.52	-1.04	.22	-.38	.75	.63	88.9	85.8	14PM
25	67	18	5.69	.68	.85	-.15	.66	.20	.70	.68	88.9	85.7	25PJ
15	65	18	4.84	.62	.72	-.50	.39	-.43	.83	.74	83.3	82.8	15PM
3	64	18	4.48	.59	.31	-2.06	.20	-1.15	.91	.76	88.9	80.5	03PB
7	64	18	4.48	.59	.68	-.67	.73	-.06	.80	.76	88.9	80.5	07PM
1	63	18	4.14	.57	.64	-.88	.46	-.70	.86	.77	83.3	78.5	01PM
			high										
8	62	18	3.83	.55	.95	.00	2.07	1.54	.68	.78	77.8	76.4	08PJ
17	61	18	3.54	.53	.72	-.74	.58	-.76	.86	.79	77.8	73.9	17PB
9	60	18	3.27	.52	.67	-.96	.52	-1.09	.90	.79	88.9	71.8	09PJ
24	57	18	2.52	.49	1.44	1.28	1.46	1.24	.71	.80	55.6	69.9	24PB
4	56	18	2.29	.48	.80	-.52	.90	-.20	.80	.80	66.7	69.5	04PM
			medium										
5	54	18	1.84	.47	1.30	.94	1.35	1.07	.58	.80	61.1	67.6	05PM
19	52	18	1.42	.46	.55	-1.59	.57	-1.51	.83	.79	72.2	65.8	19PM
22	51	18	1.21	.45	1.25	.84	1.29	.94	.72	.79	55.6	64.7	22PB
23	51	18	1.21	.45	.69	-1.01	.66	-1.10	.82	.79	77.8	64.7	23PJ
11	50	18	1.01	.45	1.38	1.19	1.32	1.01	.78	.78	55.6	63.6	11LB
20	48	18	.61	.45	.98	.03	1.03	.19	.85	.78	66.7	63.6	20PJ
2	47	18	.41	.45	.97	-.01	.94	-.11	.81	.78	61.1	64.5	02PM
10	47	18	.41	.45	1.11	.45	1.10	.40	.83	.78	61.1	64.5	10PJ
21	46	18	.21	.45	2.28	3.14	2.34	3.24	.49	.78	38.9	65.1	21LM
26	46	18	.21	.45	.55	-1.64	.55	-1.64	.81	.78	72.2	65.1	26PJ
13	45	18	.01	.45	1.24	.81	1.19	.68	.76	.77	66.7	65.4	13LM
			low										
6	43	18	-.39	.45	1.17	.61	1.16	.57	.77	.77	55.6	64.7	06PB
16	42	18	-.59	.45	1.27	.89	1.23	.77	.83	.77	50.0	65.0	16PM
12	38	18	-1.43	.47	.82	-.48	.74	-.72	.82	.77	77.8	67.9	12LM
18	37	18	-1.65	.47	.79	-.58	.70	-.82	.86	.77	77.8	68.3	18LM
MEAN	53.2	18.0	1.91	.50	.95	-.1	.94	.0			70.7	70.6	
P.SD	9.0	.0	2.16	.08	.40	1.1	.51	1.1			13.7	7.2	

FIGURE 3. Characteristics of students' concept mastery.

FIGURE 3 shows the characteristics of students' concept mastery by grouping the quality of students' concept mastery. Overall, students' concept mastery is above the average difficulty level (0.0 logit). There are four characteristics of students' concept mastery: students with very high quality, high quality, medium quality, and low-quality concept mastery characteristics. The number of students was more than 0.0 logit or achieved the quality of concept mastery in the medium, high and very high groups. These data indicate that Edmodo-assisted CBL learning can increase students' concept mastery consisting of four quality characteristics of students. This study's results align with previous studies' results, which found an increase in students' conceptual mastery through the CBL learning model (Johnson et al. 2009; Johnson and Adams 2011). Based on interviews, students followed the learning process well and enthusiastically. The results were influenced by their desire to know the concept of solving challenges. This enthusiastic attitude was also affected by challenges that are real, easy to find in the surrounding environment and useful for students to know.

The influence of Edmodo in this learning activity cannot be ignored. Edmodo helps teachers deliver complete and varied material without limited space and time. In addition, based on the qualitative data in this study, students with very high quality and high-quality characteristics actively use Edmodo as a learning tool. They actively use Edmodo to find information on solving challenges. These two groups of students can learn independently and master the concept of hydrostatic pressure through challenge-solving activities and reading material activities through teaching materials available on Edmodo. Furthermore, through Edmodo media, teachers can guide students. Previous research also found that the use of Edmodo for learning can help improve students' conceptual mastery (Pratiwi, Rochintaniawati and Agustin 2018; Vania, Setiawan and Wijaya 2018; Baharun et al. 2019), student performance in completing homework (Yalçın and Şevik 2019), and there are differences in learning achievement between students who study using Edmodo and students who use conventional learning (Vania, Setiawan and Wijaya 2018; Baharun et al. 2019). On the other hand, students with low-quality concept mastery are known to be less able to use Edmodo media due to several factors. Factors that affect low-quality students include a weak internet network and less active study group members. These factors also cause these students to have difficulty filling out student worksheets.

Student achievement at the cognitive level

Rasch model can analyze students' conceptual mastery at each cognitive level. This analysis is an essential part of completing students' concept mastery characteristics. Student achievement at the cognitive level is presented in each question based on students' logit ability value and difficulty level of the questions. Student achievement at the cognitive level of each question is shown in FIGURE 4.

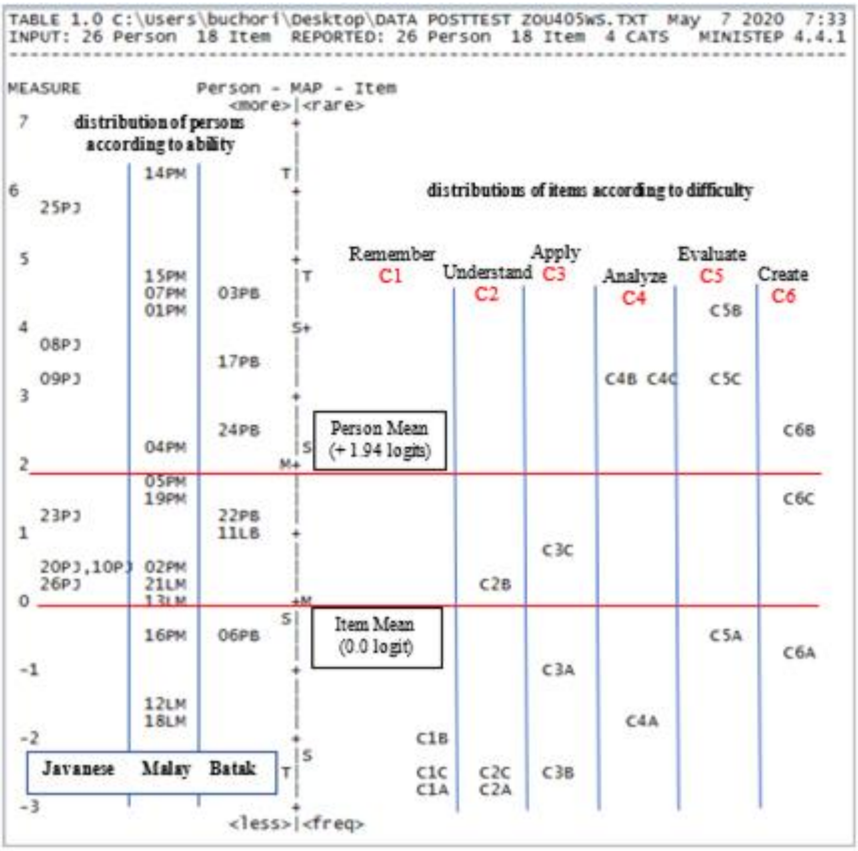

FIGURE 4. Map of person's ability and item difficulty.

The distribution of items according to difficulty has been manually grouped based on the cognitive level measured by each question. This grouping aimed to make it easier to read and analyze the distribution of students' abilities and the distribution of the level of difficulty of the questions. Question items at each cognitive level from level C1 to C6 are below the average line of students' abilities. These data provide information on the overall ability of students to master concepts well at the cognitive levels of C1 (remembering), C2 (understanding), C3 (applying), and C6 (creating). The C6 cognitive level tends to be mastered even though there are C6B questions that are slightly above the student's average ability. There is only one question for cognitive levels C4 and C5 below the student's logit ability. These two questions are questions with theme A. On the other hand, students seem to have difficulty in solving questions related to themes B and C.

The theme of question A is the concept of physics related to agricultural activities. These results indicate that the topic of physics lessons related to the discourse of expertise programs can help students master the subject matter more easily. If we look at the themes of questions B and C at cognitive levels C4 and C5, the topics in these four questions are not related to agricultural activities. This finding follows the interviews with several students in this research sample. When answering the pretest questions, students find it easier to answer questions related to the agricultural theme. Other findings were also obtained during a test of students in vocational schools with non-agribusiness of food crop and horticulture skills programs. Based on interviews with several students, they had difficulty understanding the question sentences related to the agricultural theme. Thus, this study found that the linkage of materials and physics questions to the skill program affected students' learning outcomes in vocational schools.

Overall, this study found that students' achievements at the cognitive level were sequentially remembering (C1), understanding (C2), applying (C3), creating (C6), analyzing (C4) and evaluating (C5). These results align with the research results (Furqani, Feranie and Winarno 2018), which conducted research on mastery of concepts at the cognitive level C1-C3. The study found that based on N-gain, the cognitive level of C1 has a higher category than C2 and C3. However, this finding has differences in the study results (Sani, Rochintaniawati and Winarno 2019). The N-gain scores for the cognitive level questions C1 and C2 were in a low category, C3 in the medium category and C4 obtained the high N-gain category. This result was influenced by many questions at the levels C1 and C2 questions, while the cognitive level questions C4 are equipped with many pictures and only one question requires calculation (Sani, Rochintaniawati and Winarno 2019). On the other hand, the findings (Sani, Rochintaniawati and Winarno 2019) also agree with the findings in this study. Students have difficulty answering questions on the C4 cognitive level, which require a lot of calculations and long questions. This condition is the same as experienced by the students in this study when answering questions on themes B and C.

Questions with code B discuss the concept of hydrostatic pressure in proving the purity of pertalite. On average, students cannot work on this type of question, especially questions at levels C4, C5 and C6. Question C4B is a question that measures students' ability to analyze data on two different types of pertalite to be determined their purity. In solving the problem, students must calculate the density of the pertalite based on the data and images presented. In this case, students still have limitations in using the hydrostatic pressure equation to determine the density of pertalite. In contrast, they have been able to complete the challenge of proving the purity of cooking oil. Based on information from several students, the C4B questions are relatively long and contain many numbers that must be analyzed. These two things are factors that cause students not to be able to answer the question correctly fully. Previous research also found that the low ability of students to solve problems can be influenced by questions that are long and contain many questions (Furqani, Feranie and Winarno 2018; Sani, Rochintaniawati and Winarno 2019). Then, previous research found that students tend to be able to work on questions at levels C4, C5 and C6, which contain pictures and are not arithmetical (Wandari, Wijaya and Agustin 2018; Sani, Rochintaniawati and Winarno 2019).

Students are easier to check, criticize, test something and make statements (Wandari, Wijaya and Agustin 2018). This finding is reinforced by the findings on questions C4A, C5A, C6A, and C6C. These questions measure higher-order thinking skills (HOTs) and it turns out that students tend to be able to answer the questions correctly. For example, problem C4A asks students to analyze three pictures of a dam to determine which dam is more resistant and less likely to burst. Questions to analyze like this (without using numbers and calculations) are easier for students than questions that ask students to do calculations. The same applies to questions C5A and questions C6A. On the other hand, calculation questions tend to be difficult for students to solve. For example, question C5B measures students' ability to evaluate three types of fluids to rank the types of fluids at the bottom, middle, and top of the container. The success of solving this problem is influenced by the ability of students to calculate the density of fluids. As a result, most students cannot solve the problem correctly. The same thing happened in the case of C5C. Thus, this study found that students still find it challenging to solve problems by solving numerical data and it is easier to analyze and evaluate non-calculated data.

CONCLUSION

Based on the results of this study, it can be concluded that students' mastery of concepts can be improved through a challenge-based learning model assisted by Edmodo. Qualitative data in this study showed students with very high quality and high-quality characteristics actively used Edmodo as a learning tool. They actively used Edmodo to find information on solving challenges. In addition, our quantitative data showed the characteristics of increasing students' concept mastery consist of four quality groups: very high, high, medium, and low quality. The ability of students' concept mastery is higher than the average difficulty of the questions at the cognitive level of remembering (C1), understanding (C2), applying, and creating (C6). The ability of students' conceptual mastery at the cognitively analyzing (C4) and evaluating (C5) levels was only higher on the question theme about agriculture (theme A). Meanwhile, the theme of questions B and question C was still above students' average concept mastery ability. Based on the research results, teachers can use the challenge-based learning model as a way to increase students' concept mastery.

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