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Representation and content in student's exam note sheets

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Abstract: Various forms of representation are used to understand physics concepts. This study aims to reveal the representations used by students in summarizing their physics teaching materials. The observed representations include mathematical equations, verbal statements and graphs. The participants were students who attended lectures in two academic years, namely 2016 and 2018. Students were permitted to freely write a summary of lecture material that would be used as resources during the exam. The research investigated the types of representations used and their percentages. In addition, the content in the summary was also taken into consideration. The results showed that the representation of mathematical equations or formulas, verbal explanations and graphs were used by 100%, 97% and 40% of the total students, respectively. This finding is also reflected in the percentage of paper area used in the summary; the uses of formulas are 60%, verbal explanations are 32.5% and the remaining 4.2% are graphs. Most note sheets contain almost all of teaching material. This students' tendency should be considered for teaching strategy.

Keywords*:* representations; note-sheet; equation; verbal; graph

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Introduction

Many studies show that the use of various representations such as verbal, mathematical equations, graphs and diagrams will deepen students' understanding. The graphic and visual representation have been used in teaching heat, astronomy, particle physics (Rojas & Robles, 2018; Wallace et al., 2016; Wiener et al., 2017). Multiple representations i.e. verbal, pictorial, bar chart, and mathematical representations have been introduced for studying work-energy process (Van Heuvelen & Zou, 2001). The ability to use these various representations needs to be addressed in physics learning. However, it often comes with a challenging factor such as the student's general ability to comprehend the material.

Physics understanding consists of multiple types of thinking and representation (McCaskey, 2014). In general, the representation ability is investigated by giving a test. Meltzer used both verbal and graphical tests for Newton's law problems (Meltzer, 2005). These tests allowed the author to determine which representations are comprehended by students.

In learning physics, students are expected to prepare themselves by studying the subject well. Teachers can help the students by providing home exercises and assignments. In addition, they can provide a list of formulas (formula sheet FS) related to teaching materials.

However, it has been found that the provision of formula sheets also cause problems. This is shown by the emergence of the view that studying physics means only studying the formulas (Rehfuss, 2003). Another alternative is to provide opportunities for students to bring short notes (cheat sheet CS); for example 1 book page note during an exam (Cone, 2003). With this activity

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students can receive assistance in preparing themselves prior to taking a test by writing notes that are considered important. Various articles on FS and CS, among others, examine their correlation to the performance and outcomes (Appiah-Kubi, 2016; Chang & Shieh, 2013; Danielian & Buswell, 2019; de Raadt, 2012; Song & Thuente, 2015), form, and content (Chang, 2012; McCaskey, 2013, 2015, 2014; Song et al., 2016).

Meltzer observed that there are inter representational discrepancies in student performance. It causes the different representation posed in the similar physics problem to yield different result (Meltzer, 2005). Various representations help students to develop expertise in problem solving. Additionally, students improve their understanding if they learn different representation types; they do not focus on the formula methods. (Van Heuvelen & Zou, 2001).

This study aims to reveal the representations used by students in making the note sheet and its content. In this article, the note sheet is created by the students in preparation for their exam. This is different from previous research that explored the representation from the student's response to test using a certain type of representation. In this paper, the representation is observed from the students' expressions that are done freely, which is an authentic expression of students. The observation on the students' representational tendency allow teacher to design an appropriate strategy for teaching.

Methods

This research is a case study. The participants of this research were students who were enrolled in the Atomic and Molecular Physics course. This course covers several topics such as the Rutherford-Bohr model of the atom, the Hydrogen atom in wave mechanics, many-electron atoms, and molecular structure. These topics are delivered using different representations i.e. verbal, mathematical equations, graphs and diagrams.

The research was conducted in two different academic years. In the first academic year (2016) the number of students was 67 students consisting of 35 students of class A, and 31 students of class B. The participants in the second academic year (2018) were 45 students. Students attended the lectures that are conducted by the same lecturer. In the lectures, teaching materials were delivered using various representations. Students were assigned to write a short note sheet i.e. a lecture summary prior to the exam.

The lecture summary was intended to prepare students for the exam. With this summary, it was hoped that students could comprehend the material they were studying. The summary was written on one page of a notebook. The content of the summary, the form of presentation, and the representations used were unrestricted according to the interests, abilities, and desires of the students. The students were allowed to use this note sheet during the time of the exam. Once the exam was finished, these notes were collected for observation. The observations included the representation used and aspects of form, namely in the form of completeness of items or information, whether it involves the whole material or only limited to certain parts of the material.

Here the representation is in the form of mathematical equations, verbal statements or descriptions, and graph/diagrams. The mathematical equations are comprised of basic formulas, derivative formulas, quantities and units, and related physical constants. The verbal statements or statements are in the form of explanations of concepts, events or processes. The last representation includes graph, diagrams, images, picture and tables (McCaskey, 2013, 2014). Various publications show that the students are focused on the mathematical expression to solve the physics problems (Harper, 2006; Kuo et al., 2013; Zuza et al., 2016). Meanwhile the verbal statement and graph representation are given less attention.

The tendency of the representation used by students is analyzed from the prepared summary. It is indicated by the space allocated to each representation in their summary. The data are collected from the percentage of the area used for each representation to the whole page area.

For all samples, the average percentage of paper area used for mathematical equations representation P_M is

$$P_M = \frac{\sum M_i \; n_{Mi}}{\sum n_{Mi}} \quad (1)$$

with M_i is percentage *i* of mathematical equations representation

n_{Mi} is the number of students who use the mathematical equations representation with percentage *i*

For verbal representation, the average percentage of paper area is calculated using equation (2), while the average percentage of paper area used for picture or graph representation is calculated using equation (3).

$$P_V = \frac{\sum V_i \; n_{Vi}}{\sum n_{Vi}} \quad (2)$$

with V_i is percentage *i* of verbal representation

n_{Vi} is the number of students who use of verbal representation with percentage *i*

The average percentage of paper area for graph representation follows

$$P_G = \frac{\sum G_i \; n_{Gi}}{\sum n_{Gi}} \quad (3)$$

with G_i is percentage *i* of graph representation

n_{Gi} is the number of students who use of graph representation with percentage *i*

In addition to the form of representation, the summary is also analyzed for its content. The completeness of the summary is expressed as a percentage of the total material taught in the lecture. These observations are also used to examine students' integrity in taking the exam.

Results and Discussion

Representation

The note sheets made by students are unique. In general, the note sheets are divided into columns, although there are also random ones without division. Most students divide the area of paper into three columns. By doing so they used up a full page without leaving much space. In contrast, students who summarize using two columns are leaving some free space on the page that could actually be utilized.

Figure 1 shows columns from four different samples sheet. Columns that are from 1/3 sheet are shown in panels A, B and C, while panel D is a ¼ summary. Various representations are observed in the students' summaries. In Figure 1A, the representation is a combination of mathematical equations or formula, and verbal statements. Figure 1B is an example of formula representations in the whole column, while Figure 1C shows all verbal statements in the column. Figure 1D is a summary section which has a complete representation including equations, verbal statements and graphs.

As shown in Figure 1, the summary can use representations of equations or formulas, verbal, or graph. From this summary, we can determine the percentage of area used by the representation to the whole page area. For example Figure 1B shows that the whole column contains formulas with no other representation. In this case, the column area is 1/3 of the paper area, so this column shows a formula representation of 33%. Next, each representation is calculated on the entire paper area. In this way, for all students, data can be obtained as shown in table 1 and figure 1. This data is an observation obtained from the 2016 academic year.

Table 1 shows one student uses mathematical representation only 10% of the paper area. There are 5 students whose verbal representation is 10% of the paper area. Similarly, there are 26 students who write summary with the graph representation of 10%. There are 5 students whose representation is 100% in the form mathematical equation; here they write only formula in the whole area of the paper. On the other hand there is no student whose representation is 100% verbal or 100% graph. The number of student distribution is clearly depicted in Figure 2.

From the 67 students who create the summaries, all of them use formula representations with percentage variations from 10% to 100%. Furthermore, there are 59 students who use verbal representations, while 27 students utilize the graph representation. The distribution in Figure 2 shows that the use of formula representation is evenly distributed, approaching a normal distribution. The minimum usage of formula representation i.e. 10% is carried out by one student; on the other hand, there are 5 students who used the whole paper area (100%) for the formula representation. In this distribution, most students (18) are observed to use 60% of the space as a formula representation.

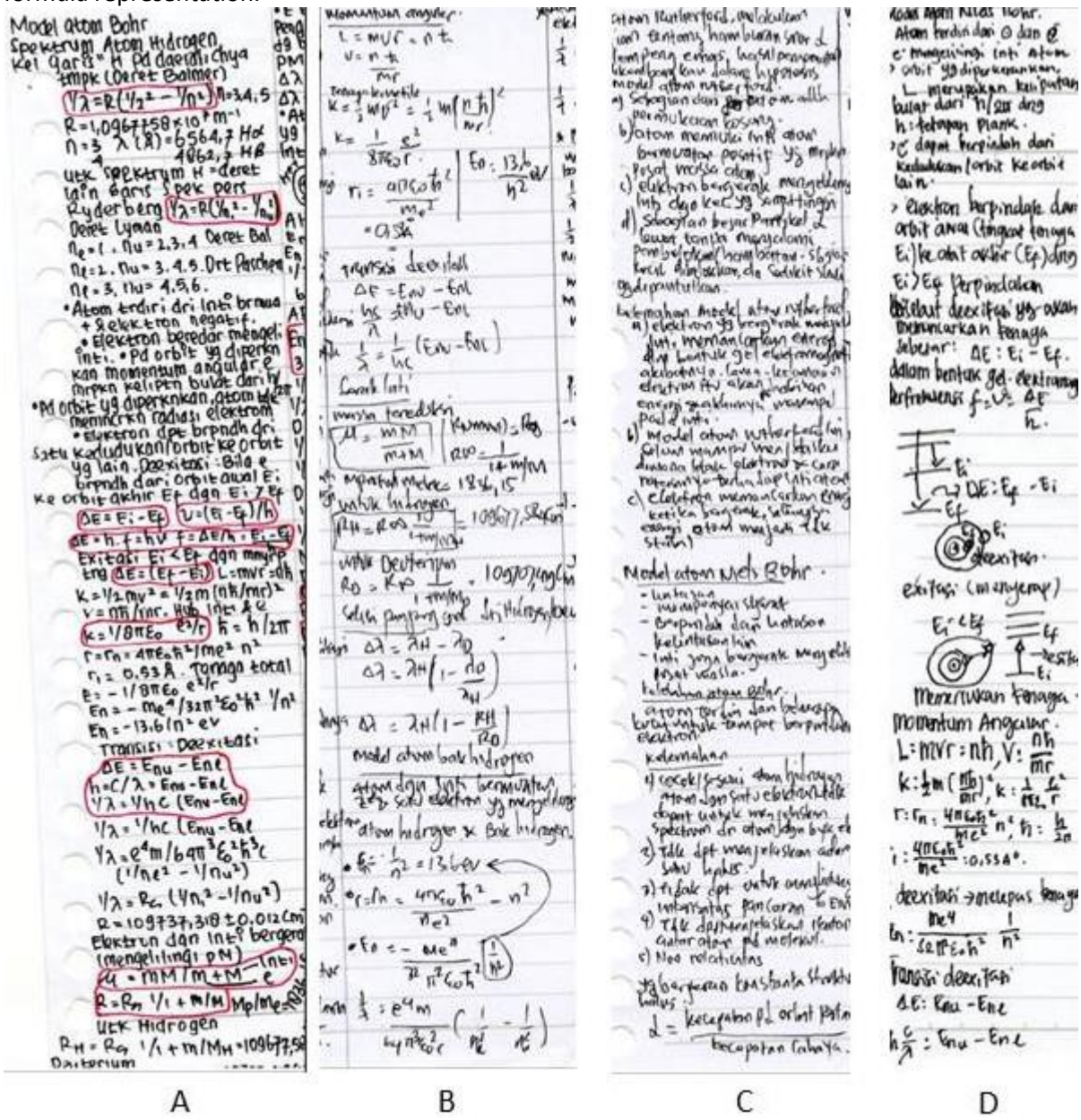

Figure 1. Example of Columns from four Different Samples

Table 1. Number of Students Who Use a Certain Percentage of Mathematical Equation, Verbal and Graph Representation in the 2016 Academic Year

	Number of students										Total students
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
Math.	1	1	4	9	14	18	3	6	6	5	67
Verbal	5	12	9	15	11	3	3	1	0	0	59
Graph	26	1	0	0	0	0	0	0	0	0	27

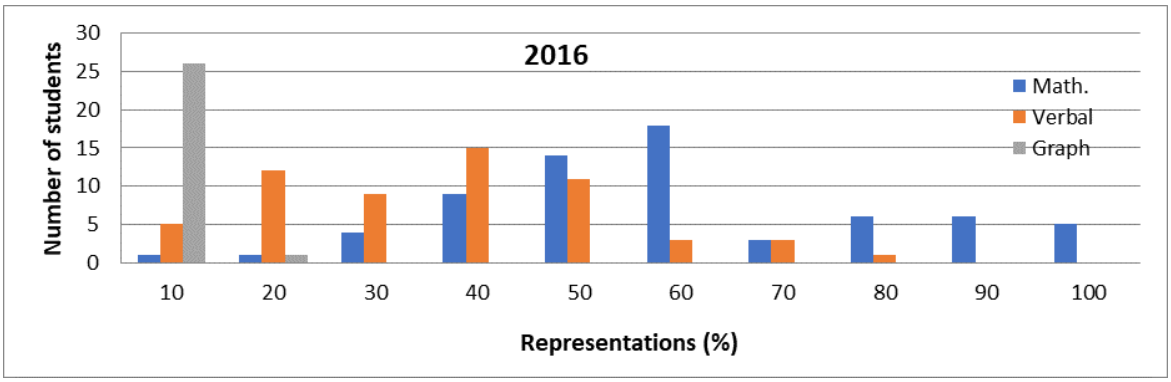

Figure 2. Distribution of the Students Who Use Mathematical Equation, Verbal or Graph Representation in their Summary for the 2016 Academic Year

There are 59 out of 67 students who use a verbal representation. They are distributed with the majority of students (15) used 40% of the area as a verbal representation in their summary. The minimum and maximum use of verbal representations is 10% and 80% of the paper area, respectively.

The Figure 2 representation is used by 27 students. The use of this representation is considered to be a few; 26 students use only 10% of the paper area in their representation. There is only one student that creates the largest graph representation, which is 20%.

The average percentage of paper area used for each representation can be obtained using equation 1, 2 and 3. For the mathematic or formula representation the calculation is done using Table 2.

Table 2. Number of Students Who Use the Mathematical Equation Representation

M_i (%)	n_{Mi}	$M_i\, n_{Mi}$ (%)
10	1	10
20	1	20
30	4	120
40	9	360
50	14	700
60	18	1080
70	3	210
80	6	480
90	6	540
100	5	500
total	67	4020

From the total value in the Table 2, the average percentage of paper area used for the mathematical equation representation can be calculated using equation (1)

$$P_M = \frac{\sum_{i=1}^{10} M_i\, n_{Mi}}{\sum_{i=1}^{10} n_{Mi}} = \frac{4020\ \%}{67} = 60\%$$

The average percentage of paper area for verbal and graph representations are obtained in the same way, the results are 32.5% and 4.2%, respectively. These results are presented in Figure 3. Figure 3 clearly shows the distribution of representations used by students in creating summaries. The numbers shown in the figure 3 are the average percentage of paper area used for each representation. The total percentage for summary is less than 100%, 3.3% of the paper area is not used. It indicates that some students do not utilize the paper area at full capacity.

In general this result reflects the orientation of students in preparation for their exam. This data at least provides an overview of the needs that are expected to assist them in solving exam questions. As shown in the data, all students consider the formula to be very important. Sixty percent of their summary is in the form of formula. This can be connected to their experience when taking the exams. Almost every exam is related to a matter of calculation; to be able to solve the problem,

they must have the formula. All students write down the formula in order to overcome their difficulties during the exam.

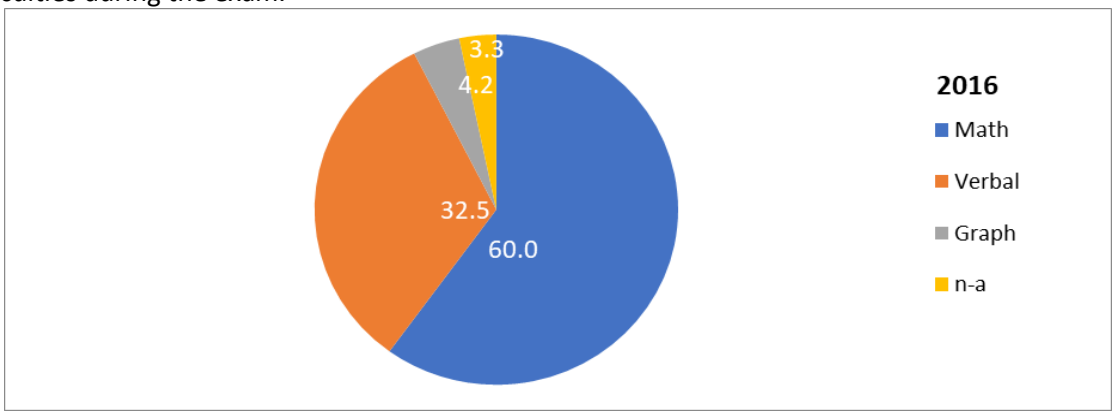

Figure 3. The Average Percentage of Paper Area Used for Mathematical Equation, Verbal and Graph Representations in the Students' Summary of the 2016 Academic Year

The formulas are written in various forms. Most summaries include almost all the formulas taught in the lecture; these writing are similar to the lecture notes. On the other hand, there are students who write only the basics formula in their summary. This indicates that the students have spent adequate time studying lecture material. They sum up and select which formulas are considered to be important. In some cases, students who are in the intelligent category, write a few formulas in their summary.

The representation of verbal statements is used by almost all students. Its usage reaches 32.5% of the available area. This reveals that students realize the importance of explanation in order to understand the teaching materials. Students still reserve the space to write the portion of the explanation, and are not just relying on formulas.

From the observations, it can be seen that the graph representation gets the least portion. This fact is related to the available teaching materials. The pictures or diagrams in the material are not as much as verbal explanations or formulas. This causes very few usages, only 4.2 % of the paper area. Nevertheless, it shows that some students recognize the importance of the graph representation and include them in the summary.

The similar situation is also observed in the test conducted in the 2018 academic year. These results are presented in Figures 4 and 5. Figure 4 shows the distribution pattern of the number of student who use formula, verbal and graph representations in the 2018 academic year. This pattern is similar to the result of the 2016 academic year as depicted in Figure 2. The formula representation is used by all participating students, with a minimum use of 10% to a maximum of 90% of paper area. The user of the formula representation is close to the normal distribution. The user of verbal representation is less than the formula representation. The usage range is between 10% to a maximum of 50% of paper area. The graph representation is very few, at most only 20%.

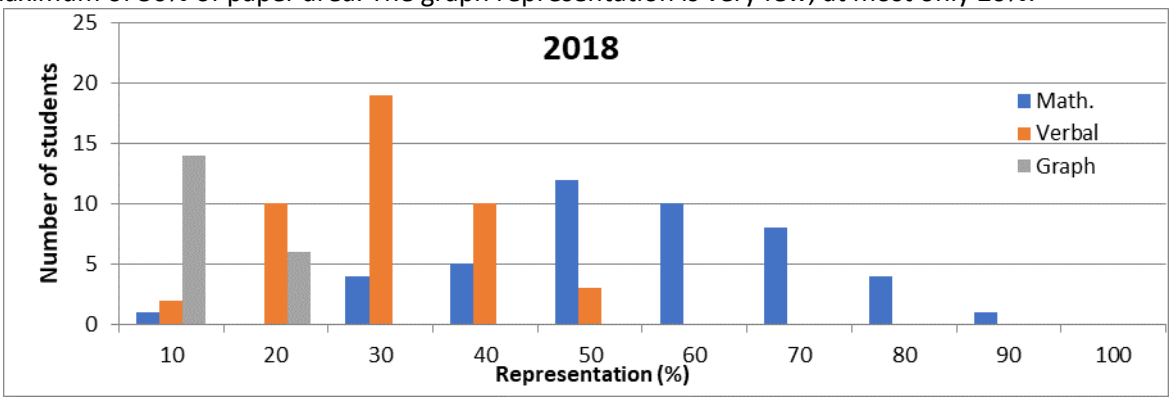

Figure 4. Distribution of the Number of Students Who Uses Mathematical Equation, Verbal or Graph Representation (%) in the 2018 Student Summary

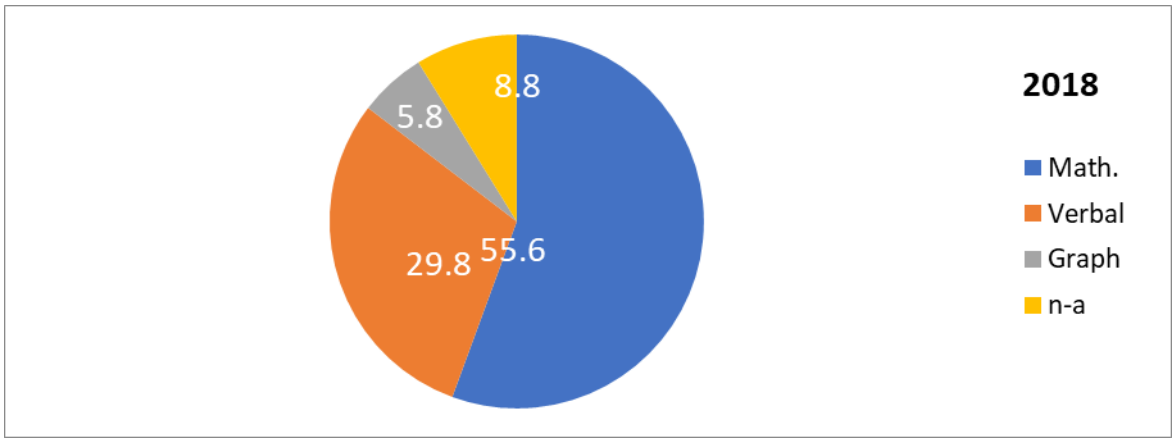

Figure 5. The Average Percentage of Paper Area Used for Mathematical Equation, Verbal and Graph Representations in the Students' Summary of 2018 Academic Year

Figure 5 point out the distribution of representations used by students of 2018 academic year in their summaries. Those numbers are the average percentage of paper area used for each representation. This situation is similar to the observation in academic year 2016 (Figure 3). A comparison of the number of students and the average percentage of paper area for a certain representation in two different academic years is presented in Table 3 and Table 4.

Table 3. The Number of Students and Related Representation

Representation	2016		2018	
	student	%	student	%
Mathematical equation	67	100	45	100
Verbal	59	96,7	44	97,8
Graph	27	40,3	20	44,4

Table 4. Average Percentage of Paper Area Used for Representation

Representation	2016	2018
Mathematical equation	60.0 %	55.6 %
Verbal	32.5 %	29.8 %
Graph	4.2 %	5.8 %

Table 3 and Table 4 show the consistency of the use of representations in students' summaries. In terms of the number of user students, the formula representation is used by all of the students. Verbal representation is used by almost all students, while those who do not use it is less than 3%. Finally, about 40% of students use the graph representations.

Observation on the paper area used for the representation shows that formula representation area is about two times of area used for verbal representation. Verbal representation takes about 30% of summaries area. About 5% of summaries area is in the form of graph or picture.

The number of students who use verbal representation is more than 97%, this number is quite large; only a small fraction (less than 3%) does not use it. Students know that the physics problems are also related to explanations, not just calculations. Therefore, they prepare themselves by writing explanations found in the lecture material, although this takes about 30% of the space.

The number of students who use graph representation is relatively large. Almost half of student include graph in their summary. This demonstrates that graphs are also needed to understand the subject in physics learning. However, the percentage of area used for the image is only about 5%. This is related to the availability of teaching materials, which is relatively smaller than the formula and verbal representation. Students only record the main pictures that might help them in solving the exam questions.

Consistent results in two different academic years shows the students' tendency to prepare for exams. All students use formula representation in their note sheet. Some students even write only formula without other representation. Students pay close attention to formulas for calculations

(McCaskey, 2015; Van Heuvelen & Zou, 2001). This tendency is in line with the results of research on students' problem-solving abilities. Students are more oriented towards solving calculation problems (Kuo et al., 2013; Niss, 2017; Santosa, 2021; Zuza et al., 2016). The focus on the numerical representation affects the students' performance. The students' score on the numerical test is higher than the explanation test. It is found that students face difficulties in the qualitative test as well as in understanding of the physics concepts (Hernández & Tecpan, 2018).

The students' representational tendency should be considered for effective teaching. Teacher can help students to improve their expertise using different representations in the course, e.g. the diagram leads to the correct equation (Harper, 2006). Teaching an appropriate strategy can raise students' understanding of physics concepts (Hill, 2016; Mason & Singh, 2016; Mualem & Eylon, 2007).

Content

The contents of the summary also vary greatly. Most students summarize the material being taught; this is distributed as presented in the table 5. The portion of teaching materials summarized by students varies greatly from 10% to complete ones i.e. all lecture materials (100%). In the case of 2016 academic year, a student only wrote 10% of the material being taught. This number of students constitutes 1.5% of the total students in that year i.e. 67 students. On the other hand, there are 20 students (29.9%) who write all teaching materials (100%) in their summary. In this academic year, there are 52 students (77.6% of 67 students) who write more than 80% of teaching materials.

A similar finding is observed in the 2018 academic year. There is a student (2.2% of 45 students) who writes only 10% of teaching materials in the summary. On the other hand, there are 16 students (35.6%) who write 100% of teaching materials. Overall, 37 students (82.2% of 45 students) write at least 80% of the teaching materials.

This result shows that most students write almost all teaching materials. Students anticipate nothing is left on their summary; hopefully it can help to solve any exam problems. On the other hand for whose content is less than 80% of teaching materials, it is found to be due to two tendencies.

Table 5. Number of Students and their Summary's Content Related to Teaching's Material

Teaching's material (%)	2016		2018	
	students	%	students	%
10	1	1	1	2
20	4	6	0	0
30	1	1	1	2
40	1	1	1	2
50	1	1	1	2
60	3	4	2	4
70	4	6	2	4
80	16	24	16	36
90	16	24	5	11
100	20	30	16	36
Total	67	100	45	100

First tendency is due to the fact that it is written by the students who do not understand the subject of teaching materials. Their writings are minimal; they only use small area of the available space. Second, in contrary to the first, students who have a complete understanding of the teaching material also do not write all subjects. Students of this category write down only the parts that needed to be recalled well. The other parts that are well understood and memorized are not written down.

Note sheet

In accordance with the given task, students create a summary according to their own circumstances. The students' response to the task of creating this summary is very good. Even before

the exam they want to get this opportunity and would feel comfortable in taking the exam. This summary reflects the needs of students to complete the exam successfully. This finding is accordance with result of Paquin et al. that most students responded positively the use of the reference sheet (Paquin et al., 2020); they felt the summary sheet writing as useful (McCaskey, 2014).

Overall for all participants, the average area of paper used is 94.5%., and it shows only 5.5% unused space. Most students optimize the available space to be filled in completely. Those who left some blank space are observed in both, students who do not understand or students who have understood the teaching materials.

In contrast to using an open book exam, the use of this summary (note sheet) stimulates students to read and learn the lecture material, and sort out which is important to be written (Hamed, 2008; McCaskey, 2015). The teaching materials cannot be transcribed completely because the paper area is limited. Thus they have to select what they really need in order to solve the exam problems. They don't write down well-understood subject. On the other hand, they also identify which teaching materials need to be prepared in order to get a good score in the exam.

The positive aspect of this note sheet assignment is it encourages students to learn; at least they read and rewrite it for themselves. Overall, this summary is unique and with no definite pattern. The form and the content are written individually; no replication is observed. The summary is really the learning outcomes of the student. Using their summary the students are ready and feel an increase of confidence to take the exams. This is one of the important provisions for the student to succeed in the exams (Cone, 2003).

The present study shows the representation used by student in preparing their exam. An additional observation e.g. by interviews will provide the details of students' choices on the representation. Here the note sheet is observed as one of the learning outcomes. The investigation has not analyzed data of the student achievement in the exam and its relation to the used representation.

Conclusion

This result provides a direct overview of student preparation for exams. Data from two different academic years show a consistent pattern. All students write down the formula in their summary. The percentage of formulas in the summary can reach 100%; the summaries only in the form of formulas representation. Almost all students also write verbal descriptions. Students who do not use verbal representations are less than 3%. Graph representation is used by about 40% of students. In general, the note sheets use at least two representations. The students have created their own summary sheet to complete the exam successfully. It is indicated by using most of the available area and writing a complete lecture material in their exam note sheet. The representation used by students reflects their understanding. It provides information to assess the ability of the students in preparing their exam as well as in identifying the important course material. The evidence of this study suggests that the appropriate teaching strategy using multiple representations is crucial to help the students in overcoming focus on the quantitative mathematical problems.

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