Identification of students’ difficulties in understanding of vector concepts using test of understanding of vector

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Abstract. This study is aimed to identify students’ difficulties in understanding vector concepts in physics because many students think that vector concept is very difficult to understand. This research used an embedded approach research design with quantitative descriptive methods and the sampling used a random sampling technique. Total sample of 142 students from two different schools in Central Lombok district. Test of understanding of vector (TUV) used to test the understanding of students consist of 20 item questions, then followed by interview session with several students. Kruskal-Wallis non-parametric descriptive and inferential statistic was used to performed data analysis. The results of this study indicate that (i) students’ ability to understand vector concepts is still lacking and tends to be very lacking; (ii) the most difficult items for students are the unit vector graphic representation and the graphical representation of vector multiplication. The concept of vector is still considered very difficult for students, especially if the item questions use graphical representations. For further researchers, it is better to conduct a study related to what kind of learning system can support and reduce the difficulties faced by students in learning vector concepts especially on graphical representation.

1. Introduction

Learning vector concepts at the beginning of school is considered very important for student. This is because of many physical quantities are defined as vectors [1]. Some examples are force, velocity, and acceleration. However, in schools today, it is found that vector concept is still very difficult to understand for students [2,3]. Students also feels like vector concept is not important [4]. So during the last few years a lot of research has focused on the vector concepts [1,2,3,4,5,6,7,8].

There have been many studies related to the vector concepts. Several researchers have analyzed misconceptions of physical quantities [5,6], students’ difficulties in representing vector concepts [3,7], and even described the relationship between misconceptions and students’ difficulties in solving vector representation problems [8]. However, research that discusses why vector concepts is considered difficult and the cause of students’ lack of understanding regarding the concept is still lacking.

Studies based on vector concept problem focus on students’ difficulties is still an interesting topic among researchers. As evidenced by many studies related to this matter. These studies focus on identifying the epistemological aspects from vector concepts [9], exploring five important transition from and difficulties epistemological and ontological axes [10], describing student difficulties regarding interpreting, constructing, and switching between representation of vector fields [3], and analyzing students’ difficulties in problems regarding unit vector notation [1]. Those research only focus on students’ difficulties but not to find out more deeply why these students find it difficult to do.

In this research we are going to explore the following: (i) students’ ability to understand vector concepts and (ii) the most difficult items for students in vector concepts. Some researchers have
investigated using this TUV [11,12,13]. However, our investigations focused on analyzing the most difficulties in students understanding of vector concepts by interviewing several students to find out the reasons for choosing each possible answer.

2. Method
This study used an embedded approach research design with quantitative descriptive methods. The research data collection used random sampling technique. Sample in the study was selected with the following criteria: 1) students who are in accredited ‘A’ schools, apply the 2013 curriculum, and have complete facilities and infrastructure to support the learning process such as physics laboratories and computer laboratories, 2) students with an average age of 15-17 years and have studied vector concept. The number of research samples was 142 students obtained from two different schools in Central Lombok with five classes. The explanation of the research subject is described in the following table:

| Table 1. Description of the research subject |
|-----------------------------------------------|
| School  | Teacher | Class      | Total student |
| SMA X   | Teacher A | XI MIPA 6 | 34 |
|         | Teacher B | X MIPA 1  | 31 |
|         |          | X MIPA 7  | 30 |
| SMA Y   | Teacher C | X MIPA     | 29 |
|         |          | XI MIPA    | 18 |

The two schools have similarities in social and environmental activities where both are in a learning environment institution located in Central Lombok Regency, West Nusa Tenggara Province. The difference is in the teacher who teaches and the learning model used when explaining concept.

The research instrument used included a multiple choice test instrument of 20 items adapted from the Physport Test of Understanding of Vector (TUV). Before being used, the instrument is first translated into Indonesian language and then a validation process is carried out by the validator. Kruskal-Wallis non-parametric descriptive and inferential statistic was used to performed data analysis. Range of values obtained is 0-100, so for each correct answer it is worth 5 and the wrong one is 0. The maximum value that can be obtained is 100 and the minimum is 0. Category of student conceptual understanding is based on the criteria adopted from Arikunto [13] shown in Table 2.

| Table 2. Categories of students’ conceptual understanding |
|----------------------------------------------------------|
| Score | Category   |
| 0 – 20 | Very less |
| 21 – 40 | Less       |
| 41 – 60 | Adequate   |
| 61 – 80 | Good       |
| 81 – 100 | Very good |

After quantitative data collection was carried out, it was followed by interviews with several students to find out the basic reasons why they chose answers.
3. Result and Discussion

3.1. Students’ Overall Score

Statistical descriptions of students’ conceptual understanding are presented in Table 3.

| Variable          | SMA X | SMA Y |
|-------------------|-------|-------|
| X MIPA 1          |       |       |
| X MIPA 7          |       |       |
| XI MIPA 6         |       |       |
| XI MIPA           |       |       |
| Total student     | 31    | 30    |
| Deviation standard| 1,69  | 1,37  |
| Minimum score     | 5     | 5     |
| Maximum score     | 40    | 35    |
| Average           | 17,42 | 19,50 |

Table 3. Statistical description

Descriptively, the average score of students who were sampled in this study was not much different. The significant value is 0.014 > 0.05, it is mean that from all the samples, there is no significant different and no need further test. If categorized, then the entire class has an average at less or even very less level on conceptual understanding in vector.

3.2. Student score on each indicator

Figure 1 below will show us the results of students' concept understanding scores for each indicator:

![Figure 1](image)

Figure 1. Score of students’ understanding of vector concepts for each indicator.

Figure 1 shows that all the correct answers that students can get are less than 30 percent. Even the highest score on the first indicator is 27.27 percent, still in the category less conceptual understanding. If we classified problem as high difficulty level if the students can get proportion of correct answer that equal to or less than 60% [11], then all the questions must be in the high difficulty level. After collecting data quantitatively, then we proceeded to collect data qualitatively to identify the reasons why students chose the two most difficult indicator on TUV, that is unit vector and scalar multiplication.

3.3. Most student mistakes

The first lowest score is in indicators 4. Indicator 4 is about unit vector which refers to the Graphic representation of a unit vector. This item is included in the category of questions with a high level of
difficulty [14]. The distribution of answers and the reasons for students choosing the options provided in these questions can be seen in Table 4.

Table 4. Percentage of answer and reasons for choosing option in question number 2.

| Option | Percentage | Argument                                           |
|--------|------------|----------------------------------------------------|
| A      | 19.72 %    | The unit vector is the same as the component vector|
| B      | 29.58 %    | The directions are same and each component of vector is 1 |
| C      | 5.63 %     | The unit vector is a normalized vector, which means its length is 1 |
| D      | 6.34 %     | The unit vector is equal to the component vector on one of the axes |
| E      | 38.73 %    | The vector shown is the same as the figure of questions |

The information obtained in table 4 shows that students tend to choose option E because the picture in the question is the same as the picture in option E. Some of the reasons that have been explained by students regarding the reasons for choosing the wrong option show evidence that students still do not really understand what is meant by the unit vector and students still find it difficult to distinguish between a unit vector in the direction of a vector and two vector components written in unit vector notation. They tend to think that this vector has a magnitude of one [2,4]. It was identified that there are misconceptions in determining the value in unit vectors and or value components on the x and y axes, as stated in previous studies that students tend to have a lot of difficulty distinguishing between unit vectors with vector sizes on different axes because of the misconceptions they have [15].

Indicator 8 is about scalar multiplication in item number 11. The problem is about Graphic representation of a vector multiplied by a negative scalar, students are asked to multiply a negative scalar by a vector. Where the distribution of student data who answered the question is presented in Table 5 below.

Table 5. Percentage of answer and reasons for choosing option in question number 11.

| Option | Percentage | Argument                                           |
|--------|------------|----------------------------------------------------|
| A      | 13.38 %    | Vector $\vec{A}$ is in quadrant II (negative) so if it is multiplied by -3 then the vector will change in size and lies on quadrant I (positive) |
| B      | 18.31 %    | Vector $\vec{A}$ is in quadrant II (negative) so for the image -3$\vec{A}$ the vector increases in size but still in its position before |
| C      | 10.56 %    | Because Vector $\vec{A}$ is multiplied by scalar -3 so it will change its length and position to quadrant IV |
| D      | 30.28 %    | Vector $\vec{A}$ moves its position on the y axis at the point -3 |
| E      | 27.46 %    | The component vector $\vec{A}$ becomes (3,3) and applies the reflection on the axis |

The information in table 5 shows that most students choose option D, where they assume that when multiplied by a negative scalar, the vector that was originally in quadrant I (positive) will move to quadrant II (negative). This assumption is influenced by their mathematical knowledge. They also have difficulty in interpreting a scalar multiplication function with a value of 3 with a vector in the form of an existing image [15].

In these two indicators, we assumed that many of students’ errors could perhaps be traced to a single major misunderstanding. They had serious conceptual confusion related to basic vector concepts represented in graphical form [6]. They seemed misunderstanding of the way vector depicted in the graphical form.

4. Conclusion

TUV is an instrument that can be used to identify the difficulties experienced by students for vector concepts. From the data that has been obtained, it can be concluded that students’ ability to understand vector concepts is still lacking because of many factors. We received information that one of the main
causes was the difficulty of students in representing vectors in graphic form. So that the advice that can be given by researchers is that teachers should focus on vector learning, especially on graphic representation. For further researchers, it is better to conduct a study related to what kind of learning system can support and reduce the difficulties faced by students in learning vector concepts.

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