Multi-perspective views of students' difficulties with one-dimensional vector and two-dimensional vector

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Abstract.Researchers of students' conceptual change usually collects data from written tests and interviews. Moreover, reports of conceptual change often simply refer to changes in concepts, such as on a test, without any identification of the learning processes that have taken place. Research has shown that students have difficulties with vectors in university introductory physics courses and high school physics courses. In this study, we intended to explore students' understanding of one-dimensional and two-dimensional vector in multi perspective views. In this research, we explore students' understanding through test perspective and interviews perspective. Our research study adopted the mixed-methodology design. The participants of this research were sixty students of third semester of physics education department. The data of this research were collected by testand interviews. In this study, we divided the students' understanding of one-dimensional vector and two-dimensional vector in two categories, namely vector skills of the addition of one-dimensionaland two-dimensional vector and the relation between vector skills and conceptual understanding. From the investigation, only 44% of students provided correct answer for vector skills of the addition of one-dimensional and two-dimensional vector and only 27% students provided correct answer for the relation between vector skills and conceptual understanding.

1. Introduction
In order to improve physics education quality, teacher needs to understand what is happening in his classroom and what are students doing and learning when they learn. According to many research, students are engaged in learning or constructing the concepts of physics and changing their prior conceptions about how the world works. Much research has been done on how students change their ideas. It is suggested that learning physics involves some rearrangement/refinement of existing concepts or maybe the elimination of old concepts (prior conceptions) and the addition of new concepts in the mind of the student. Since 1980s, Physics education research has devoted a great deal of energy and attention to the question of how to help students learn/construct the concepts of physics faster/better and the difficulties that students have in changing their prior conceptions.

Vectors are component of mathematics which is an essential language for physics[1]. Usually, senior high school students learn vectors as the first topic when they start learning their first physics course. Even in some introductory university physics textbooks, vector concepts are set as the first topic. In Indonesia, senior high school students and university students learn vectors after they have studied measurement. In university levels, especially in physics education, students learn vectors twice. In the first semester they must study about vector in fundamental physics course and in third semester they must study vector in classical mechanics course. In classical mechanics students learn

vector when they start learning their first classical mechanics course. Generally, the vector concepts consist of vector magnitude, addition, multiplication, subtraction, and component of vector. Aguirre argued that lacking of vectors understanding might cause serious difficulties when student's must study physics concepts that included vector concepts [3,7]. Garcia et al said that students' difficulty in learning physics is caused by a lack of skills and understanding about mathematics, especially vectors. Thus, understanding vector quantity is necessary in success of learning physics[2]. However, many physics education researchers found that students still hold misconception about vectors although they have studied it[4,6].

Shaffer and McDermott found that introductory students, pre-college teachers and physics graduate students have some serious conceptual and reasoning difficulties to treat velocity and acceleration as vectors in one and two dimensions [4]. Umporn and Narumon said that students still hold misunderstanding about vector addition after a traditional teaching. The students have some difficulties to add vectors graphically without any physical context. They also still confused about the "tip-to-tail" strategy add vectors graphically[7]. Barniol and Zavala said that Students who completed a calculus-based type course of mechanics have serious difficulties sketching the unit vector in the direction of a vector in the Cartesian coordinate plane[5]. Students also have difficulties with mathematical operations of vectors in which sometimes they forget the rules of the operations or they carry their difficulties with algebra into the vector operations. Barniol and Zavala also said that students face difficulties with the term of magnitude and direction or dot product with crossproduct consequently they difficult to interpret the operations [8]. Barniol and Zavalafound that, even after three introductory physics courses, students still have difficulties with vector components, in particular choosing answers with incorrect magnitudes. Some students think that the magnitude of a component is equal to the magnitude of the vector, and others know the "rule" that components are shorter than the vector, but have problems identifying the magnitude of the components graphically[9]. Barniol and Zavala found that no significant difference between the medians obtained students' understanding of vector concepts in problems with no physical context, and with three mechanics contexts: force, velocity, and work [12].

Some researchers have suggested steps to reduce misunderstanding about vector. Umporn and Narumon suggested to probe students' understanding of vector concepts even after the lesson. Active learning and teaching combined with careful instruction give much promise for helping students significantly improve their conceptual understanding [4,7]. Ostermeier et al argued that the constructivist conceptual change approaches have positive effects of students' interest and motivation as well as competencies in science and mathematics[10]. Duit and Treagust argued that conceptual change strategies may only be efficient if they are embedded in a conceptual change supporting learning environment that includes many additional features such as specially organized instruction based on models of teaching [11].

So far, the data of research about vector misunderstanding collected by written tests. However, the reports of conceptual change often simply refer to changes in concepts, such as on a test, without any identification of the learning processes that have taken place. In addition, students' interview is needed to judge conceptual change. The interviews are needed to interpret the data to avoid ambiguous decision. We argue the importance of research to explore students' understanding of one-dimensional vector and two-dimensional vector in multi perspective views in order to address to judge conceptual change with minimum ambiguous decision using test and interviews perspective.

2. Methodology

Our research study adopted the mixed-methodology design. The participants of this research were sixty students of third semester of physics education department. The data of this research were collected by test and interviews. We adopted the instrument test to asses students' understanding of one-dimensional and two-dimensional vector developed by McDermott and Shaffer (2005) and Umporn and Narumon (2011). In this study, we divided the students' understanding of one-dimensional and two-dimensional vector in two categories, namely vector skills of the addition one-

dimensional and two-dimensional vector and the relation between vector skills and conceptual understanding. The data of this research consist of two data namely essay test as quantitative data and interviews as qualitative data. Based on the incorrect answer, we choose ten students as the interviews participants.

3. Result and Discusion

3.1. Result
The essay test of vector addition one-dimensional and two-dimensional vector consist of five problems and the essay test of relation between vector skills and conceptual understanding consist of three problems.

3.1.1. Vector Addition
The problems of vector addition one-dimensional and two-dimensional presented below.
Problems 1, 2 and 3. Draw the resultant these vectors!

1)   2)   3)

4)
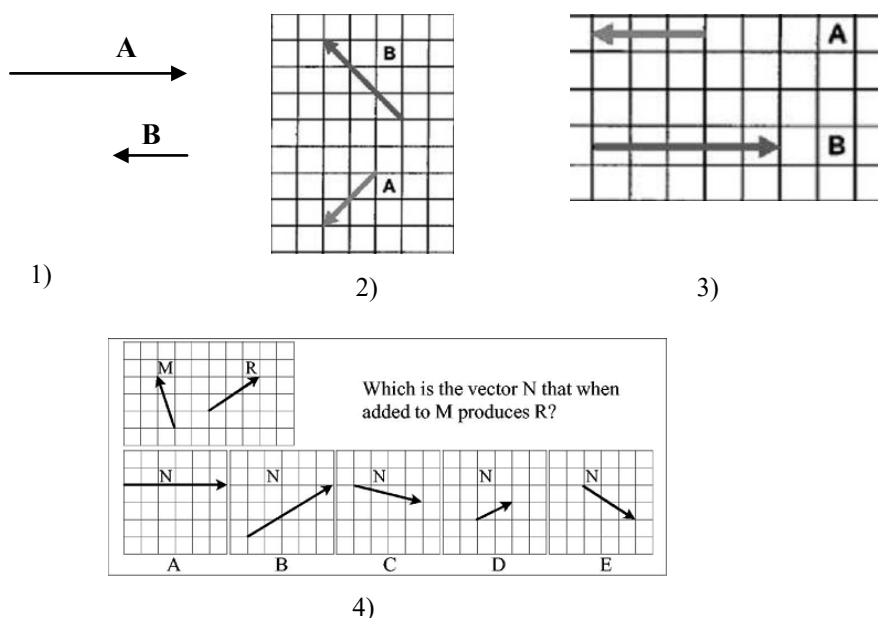
Problem 5) Generally, in vector addition **C**= **A** + **B** the magnitude **C** should just equal to magnitude A dan plus the magnitude B. Is this conclusion always correct? if vector **A** and **B** parallel, is the magnitude **C**= **A** + **B** equal to the sum the magnitude **A** and **B**? if vector **A** and **B** antiparallel, the magnitude of **C** equals the difference of the magnitude **A** and **B**?
The correct answer of students about one and two-dimensional vector addition problems presented by table below.

Table 1. The correct answer of students about one and two-dimensional vector addition problems

Problems Code	Description	Result (%)
1)	one dimensional vector addition	50
2)	two dimensional vector addition	90
3)	one dimensional vector addition	40
4)	two dimensional vector addition	20
5)	One and two dimensional vector addition	20

According to table 1, we concluded that the average of the correct answer of students about one and two-dimensional vector addition problems only 44 %. The majority of students (90%) answered the problem number 2 correctly and only 20% of students answered the problems number 4 and 5 correctly. Almost all of the students with the incorrect answered gave statement that they confused about the problems as the reason. The statement of students that they do not familiar to problem about one dimensional vector addition is shown in figure 1.
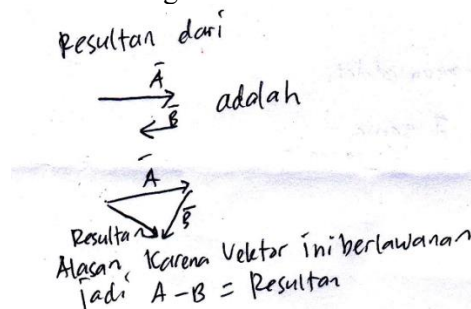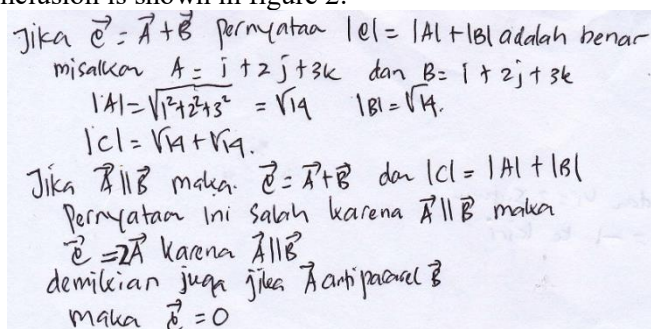

Figure 1. Screenshot of problem number 1

Most of students who answered the problems number 1 and number 3 incorrectly said that they have never known about the problem especially about parallel and antiparallel vectors in one-dimensional vector problems. Most of students who answered the problems number 1 and number 3 correctly said that they have known about one dimensional vector addition from the text book. According to the students, in classroom the lecture never teach about one dimensional vector addition. We also found that some students were still confused using the "tip-to-tail" strategy add vectors graphically. The students said that they're confused using the "tip-to-tail" strategy add vectors graphically when the magnitude and direction of vectors are different.

Based on the students' interviews, we found that their work was consistent to their statement. In spite of the problems number 2 and 4 is identical, we found that students added the vectors by creating a wrong triangle because they just adding two vectors without knowing how to do it properly. The majority of students gave the incorrect answer to the problem of two-dimensional vector additions because they forgot that vectors can be moved to make a connection.

Most of students (80%) gave incorrect answer for problem number 5. Based on the test and the interview we concluded that most of students still confused about parallel and antiparallel vectors. The prove that support our conclusion is shown in figure 2.
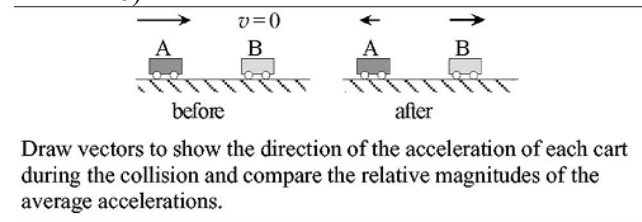

Figure 2. Screenshot of problem number 5

Based on the interview, we found that most of students that gave incorrect answer just considered the magnitude of each vectors without considering the angle between the vectors. For the problems about parallel and antiparallel vectors we found that students gave incorrect answer because they were not careful to distinguish between scalar and vector quantities.
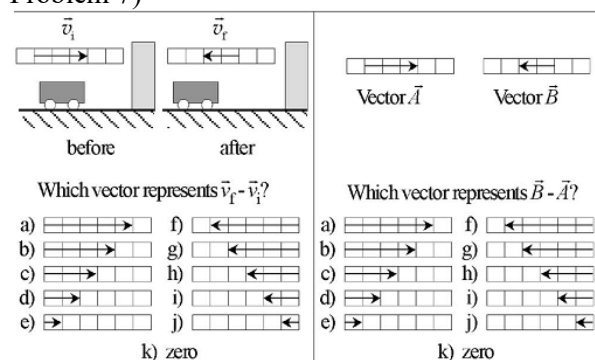
3.1.2. Vector Skills and Conceptual Understanding

The problems of vector skills and conceptual understanding presented below.

Problem 6)

Draw vectors to show the direction of the acceleration of each cart during the collision and compare the relative magnitudes of the average accelerations.
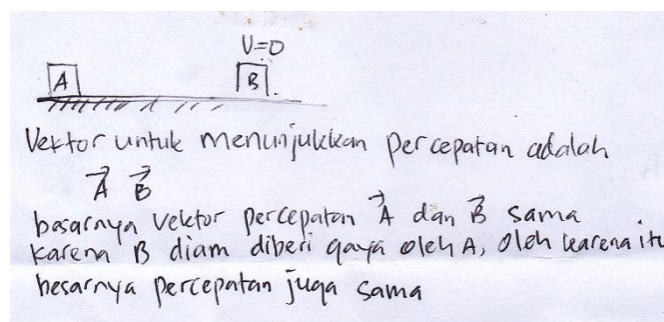
Problem 7)

Problem 8) Choose the correct response to make the sentence true: A component of a vector is (a) always, (b) never, or (c) sometimes larger than the magnitude of the vector.

The correct answer of students about vector skills and conceptual understanding problems presented by table below.

Table 2 The correct answer of students about vector skills and conceptual understanding problems

| Problems Code	Description	Result (%)
6)	one dimensional collision of two carts	20
7)	one dimensional collision of cart	30
8)	components of vector	30

According to table 2, we concluded that the average of the correct answer of students about the relation between vector skills and conceptual understanding problems only 27%. The minority of students (20%) answered the problem number 6 correctly and average 30% of students answered the problems number 7 and 8 correctly. Based on the test and interview, we found that almost all students who answered incorrectly gave a statement that they confused about the problems as their reason. The example incorrect written test answer is shown in figure 3.

Figure 3. Screenshot of problem number 6

Problem number 6 described the relation between vector skills and conceptual understanding. Most of students were unable to draw the vector in order to show the acceleration each cart during collision. According to students, the direction of acceleration during collision is same as the direction of the velocity vector before collision. The cart B has same direction to cart A because received force from cart A. Most of students could not identify the acceleration as the change of the velocities that can be found by subtracting the initial from the final velocity each cart. Based on interview to students who gave correct answer for problem 6 we concluded that they understand that velocity equivalent to acceleration, so the average accelerations is the same as for the changes in velocity, consequently cart A has the larger acceleration, which is opposite to the direction of the acceleration of cart B.

Problem number 7 and 8 also described relation between vector skills and conceptual understanding. According to the test and interview we found that most of students have difficulties about manipulation vector included physics concept or without include physics concept. The student`s difficulties of vector manipulation is shown in figure 4.
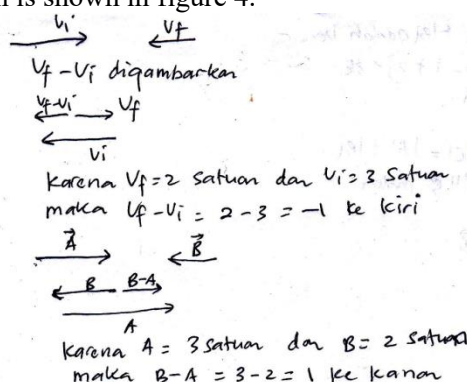
Figure 4. Screenshot of problem number 7

Problem number 7 is similar to problems number 1 and 3. We also found that the answer of students for the problems number 7, 1, and 3 were consistent. Based on the interview, we concluded that the students have difficulties to correlate the vector manipulation and the physics concept. We concluded that most of students still confused about parallel and antiparallel vectors. We found that most of students ignored the magnitude of vector to solve problems number 7 and 8. We found that the students just drawn the vector without considering the magnitude of vector accurately. The students who answered the problem number 8 correctly could use the relation between vector skills and conceptual understanding correctly. They said that based on Pythagorean theorem, the magnitude of a vector is always larger than the absolute value of each component.

3.2. Discusion

From our investigation, we found that after a conventional teaching about vector, some students ignored the direction of vector. Most of students still confused about parallel and antiparallel vectors in one-dimensional vector problems. Many students were still confused to use the "tip-to-tail" strategy add vectors graphically. We found that the students added the vectors by creating a wrong triangle because they just adding two vectors without knowing how to do it properly. The majority of students who answered the problem two-dimensional vector additions incorrectly because they forgot that vectors can be moved to make a connection although they have already taken fundamental physics and classical mechanics course. We also found that the students just drawn the vector without considering the magnitude of vector accurately. Our findings are consistent to the previous research [4,6,7, 9,12]. Based on the test and interviews, we argued the importance of improving the quality of science instruction include instructional methods.

4. Conclusion

The results of this research become complements the study on how to investigate the students' difficulties of one-dimensional and two-dimensional vector. By using multi-perspective views (test perspective and interviews perspective), we found that 44% of students provided correct answer for vector addition of one-dimensional and two-dimensional vector and only 27% students provided correct answer for the relation between vector skills and conceptual understanding. Based on the test perspective and interviews perspective we found that our finding is consistent.

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