The use of teaching semiotic vectors in the introduction to physics

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Abstract. The purpose of this study was to produce a semiotic representation-based test instrument with a multiple-choice (MMC) model that could identify vector errors in a valid and reliable manner. This research method uses the Research & Development Model (R & D) which consists of four main stages, define, design, develop and disseminate. This research was implemented to the students of 2nd semester on 2018/2019 Academic Year of physics education study program totaling 25 people. The results shown that through semiotic representation in the assessment instrument based on the multiple-choice model in a valid and reliable way, it could identify errors in understanding vector concepts (weight centers, position vectors, vector lines, and weight center coordinates) of students. From this study, the use of semiotic representations in physics assessment instruments is recommended in vector concept learning in basic physics lectures to identify errors in vector concepts to improve physics teaching.

1. Introduction

Vector is basic knowledge which is essential and fundamental in the field of science, especially physics and engineering. In physics, vectors are Euclidean quantities that have geometrical representations in one dimension, in two dimensions, or in three dimensions. A vector is also a picture or sign of a directed imaginary line.

Vector is also a component of mathematics which is an essential language for physics (Knight, 1995)[1]. This directed line is an important sign and is used extensively in physics such as the physical quantities of displacement, speed, acceleration, force, momentum, field strength, and other physical quantities. Because of the importance of vector concepts in understanding deeper concepts of physics in the future, the correct understanding of vector concepts is a good foundation for understanding subsequent physics concepts.

Understanding unit vectors is very important, because most of the concepts of unit vectors are basic concepts that determine the continued understanding of modern mechanics, thermodynamics and physics. Thus, understanding the concept of unit vectors can also be said to be the basic ladder to reach the next ladder. If the unit vector is not well mastered, students will have difficulty in understanding the next material.

Based on preliminary data findings in the pre-research conducted in semester 4 and semester 6 students of the Physics Education study program in the academic year 2018/2019 who had studied basic physics and mechanics, various errors were found in answering unit vector questions designed in the form of simple essays. The errors referred to are student errors in terms of determining the vector capture point, drawing vector lines, drawing vector directions, determining and depicting gravity vectors, determining unit vectors, and determining vector positions. The quantity of errors in answering questions designed in the form of simple essays can be shown in the following table 1:

Table 1. Quantity (%) of errors answering unit vector problems.

No.	Description	Incorrect
1	Determine the vector of tail point	53,8 %
2	Draw a vector line	56,4 %
3	Vector direction	56,4 %
4	Determine of the gravity vector	69,2 %
5	Determine of the unit vector	87,4 %
6	Determine of the position vector	87.4%

Based on the findings as shown in table 1 above, the errors that are owned by the students have not been able to accurately identify the root of the problem that is the cause of students' mistakes in understanding the concepts of unit vectors.

It turns out that the unit vector is a topic that is a lot of difficulties for students. Some researchers also found that some students still had a low understanding of the unit vector concept, even though they had learned it. Govender & Gashe (2016) found that many physics students still face difficulties in learning unit vectors [2]. In the Scientific Journal Nguyen & Meltzer (2003) revealed that 23% - 45% of students who study physics have difficulty in determining the magnitude of the vector direction, and still have a less clear understanding of what is meant by the vector direction [3]. Furthermore Mhlongo, Sithole & Moloi, (2010) suggested that students should have an adequate understanding of the basic concept of vectors if students want to succeed in teaching physics [4].

Barniol P & Zavala G (2010) identified the most common difficulties in representing unit vectors namely when sketching lines, students cannot determine the direction of vector arrows, cannot draw vectors from head to tail, cannot draw vector lines, cannot draw vectors position, and difficulties in the basic operation of the vector itself even though students have taken introductory physics courses [5]. Furthermore Barniol P & Zavala G (2012) suggested that students still face some difficulties in determining the magnitude of unit vectors through the Cartesian coordinate system (component x and component y) [6]. In fact, only 22% of students can draw unit vectors correctly. Furthermore, in subsequent studies students have difficulty in representation of unit vector graphics, vector components and in calculating vector directions (Barniol P & Zavala G, 2014) [7].

Based on the description above, it is very urgent to do in-depth research to find out and identify what obstacles are causing students to experience difficulty in capturing vector points, drawing vector lines, drawing vector directions, determining and depicting vector gravity, determining vector units, and determine the position vector. For this purpose, a multiple-choise test model (MMC) instrument was developed to detect the root causes that cause most students to experience difficulties in learning unit vectors.

2. Framework Theory

Vector is a mathematical component which is an essential language for physics (Knight, 1995). A vector is also a picture or sign of a directed imaginary line. This directed line is an important sign and is used extensively in physics such as the magnitude of displacement physics, velocity, acceleration, force, momentum, field strength. The said vector image or sign, such as OP line, is shown in Figure 1 (Vector semiotics in mechanics, Poluakan C, 2019) [8].

Vector as a directed line, the direction sign is indicated by an arrow (head) at the end of the vector that is at point P, while the base of the vector that is at point O is called the capture point of the vector (tail). In the diagram, each vector is represented by an arrow. The arrows are always drawn so that they point in the direction which is the direction of the vector. The length of the arrow is drawn in proportion to the size of the vector (Giancoli, 2001) [9].

The vector capture point also plays an important role in terms of stating the position or position of the vector. For example, for a particular object, the position of the capture point must be at the center of mass of the object or the center of gravity of the object concerned. An example of a round object as shown in Figure 2. The center of mass is at the midpoint of the round object. The gravity vector is directed downward as indicated by the directed line vector. The catch point of the gravity vector is at the center of mass of the object.

The position of the vector capture point determines the distance of the vector with another point that becomes the reference. The longer the vector's line represents the vector's size. The magnitude of a vector represents a quantity of physical quantities called scalar quantities. Physical quantities which only state great values, for example distance, rate, energy, power, and so on.

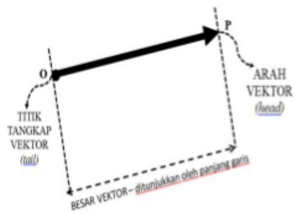

Figure 1. Tail and head of a vector.

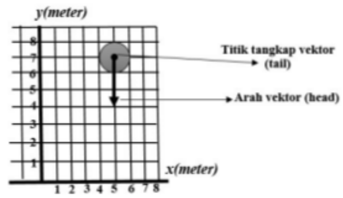

Figure 2. Tail and head of a weight.

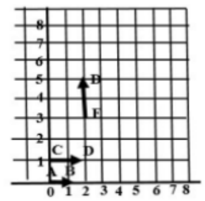

Figure 3. Vector in cartesian coordinates.

Many physical quantities are described as their place in space. Figure 3 shows how to place it using the Cartesian coordinate system. With the placement of physical vector quantities in the coordinate system means we place them in units of scale.

A unit of scale can state the identity of a physical quantity unit. For example if the vector (AB) denotes a velocity vector, then each scale unit expresses the size of the unit of speed or rate in meters per second (m / s or ms-1) or kilometers per hour abbreviated as km / hour. For a large example of speed that states 1 ms-1, then the rate or magnitude of the speed represented by the vector (AB) (by one scale) is 1 ms-1. The unit of scale can also state other physical quantities, for example in the size of the international system (SI), the unit force newton (N), unit displacement meter (m), momentum unit kg.m / s and others.

Scale units can be said to be the smallest units such as pixels. Pixels are graphic image elements that are calculated per inch. Pixels come from the English acronym Picture Element which is shortened to Pixel. Pixel scale unit density is expressed in ppi or pixels per inch. Making pictures with a computer using the pixel format.

Scale units for length dimensions can also be expressed in standard units of the International System such as meters (m), or other scales larger or smaller than meters, for example nanometers (nm), micrometers (μm), millimeters (mm), centimeter (cm), kilometer (km), and others.

The unit vector is a vector that has been broken down into the x (î), y (ĵ), z (k̂) axes, which are one unit large. The unit vector is used to explain the direction of a vector in coordinates, either two-dimensional, or three-dimensional coordinates. The unit of scale that is depicted in plane coordinates (x, y) or in space coordinates (x, y, z), then becomes the basis called unit vectors.

From Figure 4, the unit vectors in the plane coordinates (x, y) are respectively in the x-axis direction of the feeding vector î, and in the y-axis direction of the unit vector ĵ. Furthermore, for space coordinates (x, y, z) the unit vectors are î for the x-axis, ĵ for the y-axis and kˆ for the z-axis, as shown in Figure 5 below.

A vector that has a vector size of 3 units of scale, then the vector writing becomes 3î, or 3ĵ, or 3kˆ. This vector is called scalar. So scalar quantities are indicated or written in the form of numbers or positive rational numbers like 1; 2; 3; 4, ... or it can be 0.5; 1.7; 3.25; 1/3 and others. The set of scale amount is stated in symbol c, or other letters in italics.

The position of a vector in 3D space or in a 2D plane is determined by the position expressed in the unit vector $\hat{i}$, $\hat{j}$, $\hat{k}$. Vectors which are stated in the 2D plane or 3D space in units of $\hat{i}$, $\hat{j}$, $\hat{k}$ are positions related to the capture point of the vector (tail) at point O, and the end of the direction of the vector (head) at point P according to the Cartesian coordinate system.

The position of an object is a vector quantity, so it's usually called a position vector. The end of the position vector shows the point or position referred to by the position vector. The characteristic of a position vector is that it depends on the starting point. Two position vectors of the same direction and magnitude do not have to point to the same position. The two position vectors point to the same position if the base points are the same. Conversely, a point or position can also be appointed by two different position vectors at the base (Rosyid, Firmansah & Prabowo, 2015) [10].

Vectors which are stated as being in the 2D plane or 3D space with unit vectors $\hat{i}$, $\hat{j}$, and $\hat{k}$ are positions related to the capture point of the vector (tail) at point O, and the end of the direction of the vector (head) at point P according to the coordinate system cartesian.

If the vector $\vec{(OP)}$ is written as the vector $\vec{r}$, then the position vector is: $\vec{r} = x\hat{i} + y\hat{j}$. A position vector $\vec{r}$ if stated in its bases or components or may be called expressed in its unit vector, in space it can be written as: $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

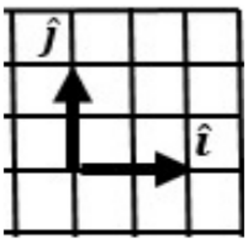

Figure 4. Cartesian coordinate unit vector in two dimensions.

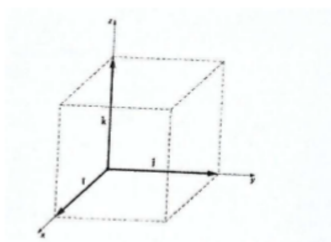

Figure 5. Cartesian coordinate unit vector in three dimensions.

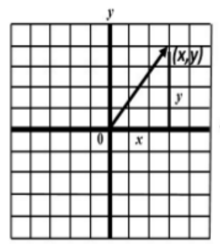

Figure 6. One position vector in Cartesian coordinates.

3. Methodology

This research was carried out in the Physics Department of Manado State University Physics Education Study Program in the semester 2 students of the 2018/2019 academic year totaling 25 people. This study uses a 4-D development model developed by Thiagarajan which consists of 4 stages: the defining stage, the design stage, the development stage, and the disseminate stage. 1) Defining stage: what is defined in this study is the physics concept that will be used as research material is the center of weight, vector position, vector lines, and coordinates of the center of weight. 2) Design Phase: At this stage a semiotic representation-based test instrument design with a multiple-choise (MMC) model is performed. 3) Development Phase: at this stage the instrument test is based on a semiotic representation with a multiple-choise (MMC) model that has been designed validated by material experts and evaluation experts so it is believed to have high validity as an instrument test. 4) Dissemination Stage: This stage is the stage of using a semiotic representation-based test instrument with a multiple-choise (MMC) model in teaching physics and followed by interviews to be able to accurately identify vector missconcept.

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4. Result and Discussion

The following will present the Model Multople-choise (MMC) test instrument used in detecting the causes of student miss-concepts related to unit vector topics.

1. Vector from point (3,5) to point (9,13); and from point (19,15) to point (6,17) shown in the figure?

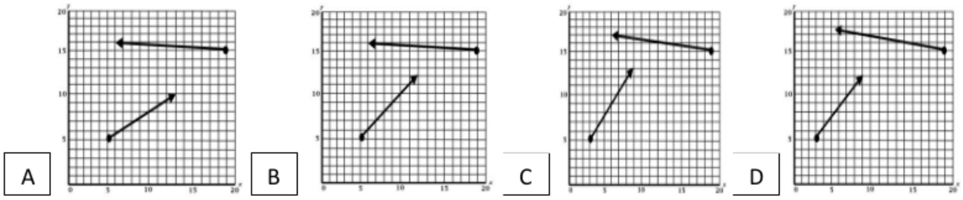


Figure 7. Test instrument for the position of a vector.

Of the 25 students who worked on the test instrument, 12% answered correctly, while 88%

2. If each geometrical shape has a gravity expressed in a unit vector $\vec{w}$ = -3j, then the position of the center of weight vector $\vec{w}$ for each geometric object is shown in the figure:

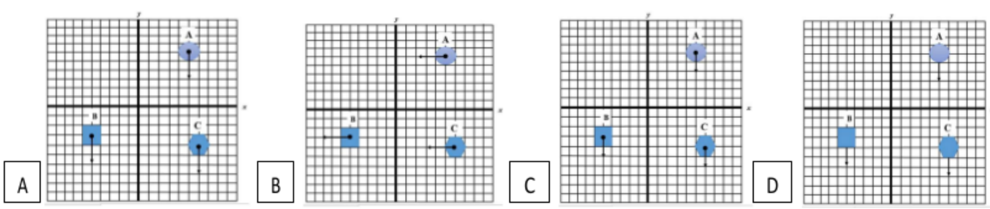
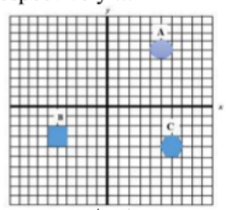


Figure 8. Test instrument for position vectors identified they generally do not understand the position of the coordinates.

answered incorrectly. From the results of interviews with students who answered incorrectly

Of the 25 students who worked on the test instrument, the correct answer was 20%, while 80% answered incorrectly. From the results of interviews with students who answered incorrectly identified they generally do not understand about unit vectors and scale units in the coordinate system, and the center of weight.

3. Based on the figure below, the position vector from the coordinates of the center of gravity of the three geometric fields A, B and C, respectively ...



A.	B.	C.	D.
$\vec{A} = 5i + 6j$	$\vec{A} = 6i + 5j$	$\vec{A} = -8i + 6j$	$\vec{A} = -5i + 6j$
$\vec{B} = -5i + -3j$	$\vec{B} = -3i + -5j$	$\vec{B} = -5i + 5j$	$\vec{B} = 6i + -3j$
$\vec{C} = 6i + -4j$	$\vec{C} = 6i + -4j$	$\vec{C} = -10i + -4j$	$\vec{C} = 4i + -6j$

Figure 9. Test instrument for three position vectors.

Of the 25 students who worked on the test instrument, 16% answered correctly, while 84% answered incorrectly. From the results of interviews with students who answered incorrectly identified vector concept errors as shown in table 2 below:

Table 2. Description of student missconception

No.	Description	Missconception
1	Don't understand the coordinates	88 %
2	Don't understand unit vectors	72 %
3	Don't understand the unit of scale in the coordinate system,	80 %
4	Don't understand position vector.	88 %
5	Do not understand the center of weight	84 %

From the findings in this study, it can be ascertained that the mistakes of students in learning unit vector topics as described in table 1, namely student errors in terms of determining vector capture points, drawing vector lines, drawing vector directions, determining and depicting gravity vectors , determine the unit vector, and determine the position vector caused by most students do not understand correctly about the coordinate point in the coordinate system, do not understand correctly about the unit vector, do not understand about the unit of scale in the coordinate system, do not understand about the position vector, and do not understanding the center of weight of an object of various shapes as shown in table 2.

It turns out that the unit vector is a topic that is a lot of difficulties for students. This is also consistent with previous studies conducted by Barniol P & Zavala G (2010) who identified the most common difficulties in determining vector direction, drawing vector lines, not understanding the head and tail vector, as well as difficulty determining the position vector.

5. Conclusion

From the results of the study it is understood that students' understanding of determining vector capture points, drawing vector lines, describing vector directions, determining and depicting gravity vectors, determining unit vectors, and determining vector positions are carried out at the pre-research stage using a simple essay model test instrument most students only answer questions without being based on their understanding of vectors even they generally answer by trying to see the work of their friends. It is therefore difficult to identify the source of students' misconceptions about the concept of vector capture points, draw vector lines, draw vector directions, determine and depict vector gravity, determine unit vectors, and determine position vectors. By using the Multiple-Choise Model (MMC) instrument test and followed by interviews with students about the answer to the questions, the known and identified source of misunderstanding of the vector concept is that the students do not understand what the coordinate points are. Also in drawing vector lines they do not understand that the length of the vector lines has significance that indicates the size and direction of the vector. It was also identified that there were students who did not know how to determine the unit vector in terms of starting to determine the unit of scale in the coordinate system which also resulted in being unable to determine the position vector. Thus it can be concluded that by using a multiple-choise model test instrument can accurately identify students' understanding of vector concepts. Through this research it is recommended the use of semiotic representation in physics test instruments in learning vector concepts in basic physics lectures to identify misconception of vector.

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