

# A Worksheet to Enhance Students' Conceptual Understanding in Vector Components

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**Abstract.** With and without physical context, we explored 59 undergraduate students' conceptual and procedural understanding of vector components using both open ended problems and multiple choice items designed based on research instruments used in physics education research. The results showed that a number of students produce errors and revealed alternative conceptions especially when asked to draw graphical form of vector components. It indicated that most of them did not develop a strong foundation of understanding in vector components and could not apply those concepts to such problems with physical context. Based on the findings, we designed a worksheet to enhance the students' conceptual understanding in vector components. The worksheet is composed of three parts which help students to construct their own understanding of definition, graphical form, and magnitude of vector components. To validate the worksheet, focus group discussions of 3 and 10 graduate students (science in-service teachers) had been conducted. The modified worksheet was then distributed to 41 grade 9 students in a science class. The students spent approximately 50 minutes to complete the worksheet. They sketched and measured vectors and its components and compared with the trigonometry ratio to condense the concepts of vector components. After completing the worksheet, their conceptual model had been verified. 83% of them constructed the correct model of vector components.

## 1. Introduction

Previous studies [1-2] had shown that students have difficulties in many concepts of vectors. The research also found that students still hold misconception about vector components although they have studied it before. These bring difficulties to their physics learning. Physics education researchers had created various instructional tools for physics teaching. Tutorial worksheet was one of the most powerful tools that physics instructors have used to help their students learned about vector concepts. There were some research results indicated that students had performed well after the worksheet instruction [3-4]. The worksheet tools are very convenient and time saving. Therefore, we intended to design a worksheet to enhance students' conceptual understanding in vector components.

## 2. Methodology

We explored undergraduate students' conceptual and procedural understanding of vector components using both open ended problems and multiple choice items [6-7]. Two equivalent open ended problems, with and without physical context, had been modified from the work of Deventer and Wittmann [6]. The problems asked students to find magnitude and graphical form of vectors. The problems were given to 59 junior students in science teacher preparation program. The students spent approximately 15 minutes to complete the open ended problems. The 3 multiple choice items of the Test of Understanding of Vector (TUV) [7] have been applied to the students as well. The multiple choice items asked students to choose correct answers about graphical vector components in  $x$ - and  $y$ -axes and its numerical magnitudes. In order to avoid duplication, the students have to complete the open ended problems before starting with the multiple choice items. They spent approximately 15 minutes more for completing these items. Consequently, the students' open ended responses were classified based on the similarity of errors performed in the responses and multiple choice items were scored. Based on the findings, we designed a worksheet to enhance students' conceptual understanding. The worksheet validation had been conducted using focus group discussions of 3 and 10 graduate students (science in-service teachers). The modified worksheet was then distributed to 41 grade 9 students who started learning vector components in their science class. The students spent approximately 50 minutes to complete the worksheet. After completing the worksheet, their conceptual model had been verified.

## 3. Student Conception in Vector Components

The investigated results of student conception in vector components showed that a number of students produce errors and revealed alternative conceptions especially when asked to draw graphical form of vector components. 12% of the students provided correct numerical magnitude of vector components while 42% of them provided just graphical form without numerical magnitude. 20% of them tried to calculate magnitude of the provided vector. 14% of them confused the magnitude of  $x$ -component with  $y$ -component including both their magnitudes and symbols. The last 12% provided different answers with sine and cosine functions. When focusing on graphical form of vector components, very few of the students gave correct answers. 22% drew longer and/or shorter vector components. 44% were aware of the graphical magnitude of the vector components but still provided incorrect responses. 29% drew vectors in different forms or wrote down other symbols. With physical context, only 2 students provided correct answers in numerical magnitude and graphical form of vector components. 31% drew longer and/or shorter vector components and most of them (39%) drew other force vectors in the other axis instead.

For their multiple choices' responses, the results showed that 20% of the students provided all correct responses about graphical vector components in  $x$ - and  $y$ -axes and its numerical magnitudes. 19% provided correct responses only on graphical magnitude in  $x$ - and  $y$ -axes. The other 61% provided just one correct or all incorrect responses.

These were consistent with the previous findings in physics education research. It indicated that most of them did not develop a strong foundation of understanding in vector components and could not apply those concepts to such problems with physical context. These results confirmed the need for new instructional material to foster students' understanding in vector components.

## 4. Design of Worksheet

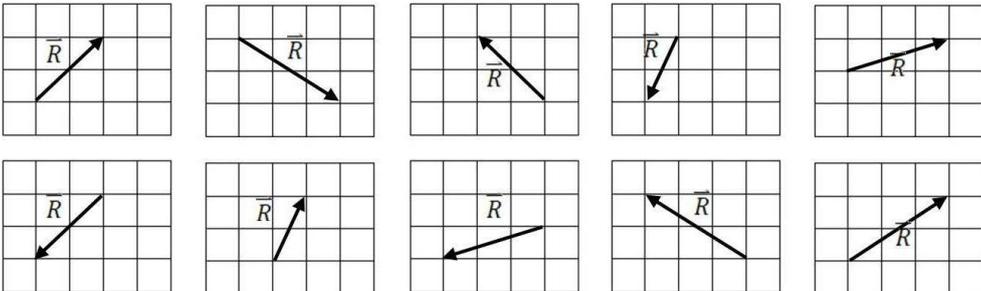
Based on the findings, we had designed a worksheet which help students construct their own understanding of definition, graphical form, and magnitude of vector components. There were three parts in the validated worksheet: 1) definition and graphical form of vector components; 2) magnitude of vector components; and 3) conceptual model of vector components as presented in figure 1.

### 4.1 Part 1: Definition and Graphical Form of Vector Components

To make students understand the definition and graphical form of vector components, we asked students to determine and draw vectors  $\vec{P}$  and  $\vec{Q}$  in only vertical and horizontal axes, respectively, that can form

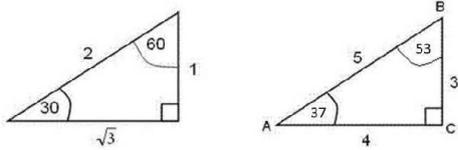
vector  $\vec{R}$ . The students will come up with two component vectors in vertical and horizontal axes. We then provided the definition and symbols of vector components.

**Part 1: Definition and Graphical Form of Vector Components**  
 Draw  $\vec{P}$  and  $\vec{Q}$  only in vertical and horizontal axes where  $\vec{R} = \vec{P} + \vec{Q}$



The drawn  $\vec{P}$  and  $\vec{Q}$  vectors are called **vector components** where **y-component** is  $\vec{R}_y$  and **x-component** is  $\vec{R}_x$

**Part 2: Magnitude of Vector Components**



a. Draw  $\vec{R}$  in three different magnitudes where  $\vec{R}$  is  $53^\circ$  with the horizontal axis. Measure the magnitudes of x- and y-component and complete the table.

$\vec{R}$ (cm)	$\vec{R}_y$ (cm)	$\vec{R}_x$ (cm)	$\frac{ \vec{R}_y }{ \vec{R} }$ (cm)	$\frac{ \vec{R}_x }{ \vec{R} }$ (cm)	$\frac{ \vec{R}_y }{ \vec{R}_x }$ (cm)
<b>average</b>					

b. Compare the proportion of  $\frac{|\vec{R}_y|}{|\vec{R}|}$ ,  $\frac{|\vec{R}_x|}{|\vec{R}|}$  and  $\frac{|\vec{R}_y|}{|\vec{R}_x|}$  with the Trigonometry of  $53^\circ$

$\frac{ \vec{R}_y }{ \vec{R} } = \text{_____} 53^\circ$	$\frac{ \vec{R}_x }{ \vec{R} } = \text{_____} 53^\circ$	$\frac{ \vec{R}_y }{ \vec{R}_x } = \text{_____} 53^\circ$
$ \vec{R}_y  = \text{_____}$	$ \vec{R}_x  = \text{_____}$	

c. Draw  $\vec{R}$  in three different magnitudes where  $\vec{R}$  is  $30^\circ$  and  $60^\circ$  with the horizontal axis respectively. Follow the steps a to b.

**Part 3: Concept model of vector components**

- Sketch and find magnitudes of x- and y-component of  $\vec{A}$  where  $\vec{A}$  forms an angle  $\theta$  from vertical axis.
- Sketch and find magnitudes of x- and y-component of  $\vec{A}$  where  $\vec{A}$  forms an angle  $\theta$  from horizontal axis.

**Figure 1.** The worksheet of vector components

#### 4.2 Part 2: Magnitude of Vector Components

To grasp the concept of magnitude of vector components, students have to follow the steps a) to c) in the worksheet. The students will find out about numerical magnitudes of component vectors in  $x$ - and  $y$ -components.

#### 4.3 Part 3: Conceptual Model of Vector Components

This is an evaluation part. Completing parts 1 and 2, the students had sketched and measured vectors and their components and compared with the trigonometry ratio. These help them condense the concepts of vector components. They should come up with the conceptual understanding of vector components. Therefore, we asked them to generate their conceptual model and then, the model will be verified.

### 5. Implementation of the Worksheet

The implementation of the worksheet was carried out by an experienced science teacher without lecturing or giving answers, but rather help students to arrive at their own answers by posing questions that guide them through the necessary reasoning. After conducting the worksheet with 41 grade 9 students, we found that 83% of the students provided correct model of vector components. 12% of them tried to find out numerical answers for part 3 and did not come up with the correct model of vector components. The other 5% provided no answer. In addition, it should be reminded that students should complete their lessons about vector addition and trigonometry before learning with the vector component worksheet.

### 6. Conclusion

These study results had shown that many students have difficulties in vector components and could not apply those concepts to problems both with and without physical context. These confirmed that we need new instructional material to foster students' understanding. For this study, there are some evidences indicated that our designed worksheet could be used to enhance students' conceptual understanding in vector components. Almost all of the students could construct the correct model of vector components after the worksheet instruction. With the worksheet, students could construct their own understanding of definition, graphical form, and magnitude of vector components instead of learning by memorizing the way to compute and attribute little meaning to them.

### Acknowledgement

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