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ELEMENTARY EDUCATION STUDENTS' UNDERSTANDING LEVELS OF ONE DIMENSIONAL MOTION AND INSTRUCTORS' PREDICTIONS RELATED TO THEIR RESPONSES

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Abstract:
The purpose of the study is to investigate the elementary education undergraduate students' understanding levels of one dimensional motion which they take in the compulsory general physics course in the second year, third term and instructors' predictions about the students' responses. The study is a descriptive study. The data of the study were collected via an interview form consisting of three multiple choice questions and one open ended question developed by the researcher considering the expert opinions. Seven students were chosen randomly from the population relying on volunteers and having spare time and semi-structured interviews were carried out with these students individually. In addition, just after the questions were asked to the students, face-to-face interviews were carried out with five experienced faculty members teaching general/basic physics courses in the same faculty. It was revealed that among the elementary education students 30.7% of students perceived that average speed and average velocity were different quantities, 33.3% of students calculated correctly the value of the velocity of the car starting from rest and speeding up at a constant acceleration on a straight line considering the distance travelled, and 29.3% of them calculated correctly the negative acceleration (or deceleration) of a moving car which slows down at a constant acceleration on a straight line and 10.7% of the students calculated correctly the similar distance travelled by another car moving with a constant acceleration while coming to a rest when it caught up the car moving with a constant speed on a straight line in the same direction. It was revealed that among the participants, the rate of the students who answered the questions correctly were at low levels which required to be examined, thought, discussed, and considered. The percentages of the instructors' predictions about the responses of elementary education undergraduate students whom they teach linear motion in general physics course reveal that they usually do not adequately know their students' understanding levels of linear motion and their problems about the subject.

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Keywords: elementary education undergraduate students, one dimensional motion, understanding level, instructors' predictions

1. Introduction

The subject of one dimensional motion is usually included in the second section in the course books developed for the students who will take basic/general physics courses involved in many undergraduate programs of the universities (Young & Freedman, 2009, pp. 36-60; Serway & Beichner, 2010, pp. 23-55; Halliday, Resnick & Walker, 2014, pp. 13-37). Including one dimensional motion just after vectors, a basic subject, in the course books (Young & Freedman, 2009, pp. 36-60) will make it easy for the instructors who teach the subject and the learner who tries to learn the subject as the quantities which learners encounter in linear (one dimensional) motion are vector quantities. Linear motion (also called motion along a straight line) usually is taught with regard to following sub-titles: definition of motion, position and displacement, average speed and average velocity, instantaneous speed and velocity, average acceleration, instantaneous acceleration, constant acceleration and free fall. Moreover, position-time graphs, velocity-time graphs, and acceleration-time graphs are drawn for one-dimensional motion and their characteristics are specified. According to the documents analyzed (Young & Freedman, 2009, pp. 36-60; Serway & Beichner, 2010, pp. 23-55; Halliday, Resnick & Walker, 2014, pp. 13-37), it can be stated that the order in which the sub-titles of linear motion are taught is appropriate for the hierarchical teaching of concepts. Except for the engineering and science programs, physics must be included in some undergraduate programs like elementary education undergraduate programs as an introduction to physics course (Mazur, 2015).

The students taking introduction to physics course must be taught linear motion or one-dimensional motion at a much simpler level and many and different examples must be solved. Instead of avoiding the subject by giving formulas and equations, it is important that their important properties and examples should be given conceptually with a simple language. In case of need, undergraduate students of elementary education can be excused from some sub-titles.

The research carried out revealed (Yıldız, 2014a; Yıldız, 2016a; Yıldız, 2017a) that university students had some serious problems about the vector quantities. It can be stated that students who are supposed to construct quantities related to linear motion on their existing knowledge about vector quantities have some problems (Gunstone & Watts, 1985; Arons, 1990; Borghi, De Ambrosis & Massara, 1993; Yıldız & Büyükkasap, 2006; Yıldız, Büyükkasap, Erkol & Dikel, 2007; Yıldız, Büyükkasap, & Günel, 2011). It was stated in another current study that mathematics teachers who prepared and solved mathematics questions about motion problems perceived-used the quantities of average speed and average velocity not as different quantities but the identical quantities (Yıldız, 2017b).

It is predicted that the students who cannot learn the basic-fundamental properties and principles of vectors and vector quantities will experience some problems while learning quantities about linear motion like position, displacement, average speed, average velocity, instantaneous velocity, average acceleration, and instantaneous acceleration. It is important to know the understanding levels of students studying in undergraduate program of elementary education and taking compulsory general physics course about the topic of one dimensional motion so that possible challenges can be detected.

1.1 The Purpose of the Study

The purpose of the study is to investigate the understanding levels of undergraduate students of elementary education about one dimensional motion which they take in the compulsory general physics course in the second year, third term and instructors' predictions about the students' responses.

2. Method

The study is a descriptive study. A total of 75 students, 61 female and 14 male, in their second year of studies in the undergraduate program of elementary education in the department of basic education in education faculty in a state university and taking compulsory general physics course in the third term participated in the study. Based on the participant students' declaration of their achievement in general physics course in terms of letter grade, it was determined that 12 students got AA, 8 students BA, 14 students BB, 15students CB, 11 students CC, 8 students DC, 5 students DD and 2 students FF. The data of the study were collected via an interview form consisting of three multiple choice questions and one open ended question about linear motion developed by the researcher considering the expert opinions. The participants' responses to the multiple choice questions considering the choice, their written responses to the open-ended question, and their explanations were analyzed and they were grouped in terms of their content, similarities, and parallelism. The responses categorized, females-males who chose and wrote the answers, total number of students, percentages, and instructors' predictions about the percentages of the given responses were tabulated in different columns. Necessary interpretations and explanations were made at the end of each table.

Out of 75 undergraduate students who expressed their opinions about vectors, semi-structured interviews were carried out separately with 7 students chosen randomly from the population relying on volunteers and having spare time. In addition, just after the questions were asked to the students, face-to-face interviews were carried out with five experienced faculty members who taught general/basic physics courses in the same faculty in the past during the term the study was carried out and most probably will continue to teach. The instructors were asked to predict the responses of the students to the questions about linear motion and at what percentages (9%, 15%, 32%,...) these responses were chosen/written. The arithmetic average of the percentages about each question taken from the instructors was calculated and they were presented in the rows and the columns where there are relevant student responses. No recording was made during the interviews when it is considered that the participants would be troubled or would not essentially like to be recorded, thus, a recorder of any kind was not used during the interviews.

3. Findings

3.1 Question 1

A farmer starts walking from his cottage located in the corner of his rectangular field (width 250 metres, length 350 metres) planted with watermelon and he walks around his field in the same direction only once. The farmer measures this 20 minute walk with his wrist watch. What is the magnitude of the farmer's average velocity in m/s?

a) 60 b) 30 c) 20 d) 1 e) 0

Table 1: Elementary education students' responses related to the magnitude of the farmer's average velocity

Student Responses	Male	Female	Total	%	Instructors' Predictions (%)
60	6	15	21	28.0	20.0
30	1	4	5	6.7	4.0
20	-	2	2	2.7	6.0
1	5	19	24	32.0	20.0
0	2	21	23	30.7	50.0
Total	14	61	75	100	100

The first question which was developed carefully by the researcher considering its numerical values and statement aims at questioning students' opinions and knowledge about average velocity. The answer zero (0) chosen by only 30.7% of the students participating in the study is correct. Those (28.0%) who chose 60 m/s are the participants who are likely to divide the perimeter of the field (distance travelled) by the time of travel (20 minutes) to compute average speed, but not average velocity. Another problem of these students who chose the first choice (60m/s) is that they ignored the second which is a basic physical quantity and also accepted as unit of time in SI units of measurement. The students who chose the value of 1 m/s are those who divided the perimeter of the field, 1200 m, which is the distance travelled by the time of travel, in place of average velocity which is computed by dividing displacement by time; in other words, they computed average speed in place of average velocity. When Table 1 is examined, it is understood that 60.0% of the elementary education students perceived average speed and average velocity as the identical quantities, but not as different quantities. It is more likely to state that similar condition is true for the distance travelled and displacement because understanding that average speed and average velocity are different quantities requires to understand that the distance travelled and displacement are different quantities. The findings of some studies (Yıldız, 2016a; Yıldız, 2017a) seem to support this opinion. Although 69.3% of the students could not choose the correct answer, it is found that the instructors' predictions about them are 50.0%. It is clear that there is not a consistent, compatible, and accurate situation existing between the students' responses and instructors' predictions about these responses.

3.2 Question 2

The car starting from rest speeds up with constant acceleration on a linear track and takes 2500 metres in 50 seconds. What is the magnitude of the car's velocity at the end of 2500 metres in m/s?

a) 40 b) 50 c) 60 d) 80 e) 100

Table 2: Elementary education students' responses related to the magnitude of the car's velocity

Student Responses	Male	Female	Total	%	Instructors' Predictions (%)
40	-	1	1	1.3	8.0
50	7	39	46	61.3	10.0
60	-	1	1	1.3	7.0
80	1	1	2	2.7	15.0
100	6	19	25	33.3	60.0
Total	14	61	75	100	100

When Table 2 is examined, it can be understood that 33.3% of the elementary education teachers could correctly compute or choose the velocity of the car which starting from rest speeds up with constant acceleration at the end of the 2500 metres and the instructors' predictions about their students' responses were 60.0%.

3.3 Question 3

The bus driver driving with the velocity of 30 m/s sees a lorry loaded with freight moving with the constant velocity of 10 m/s in the same direction 200 metres away from himself and he has to apply the brakes in order not to crash into the back of the lorry. What is the minimum deceleration of the bus in m/s^2 when braking in order to avoid crashing and also for two vehicles to move?

a) 0.25 b) 1.0 c) 0.75 d) 0.50 e) 1.2

Table 3: Elementary education students' responses related to the deceleration of the bus when braking

Student Responses	Male	Female	Total	%	Instructors' Predictions (%)
0.25	2	4	6	8.0	8.0
1.0	4	18	22	29.3	50.0
0.75	5	20	25	33.3	10.0
0.50	2	13	15	20.0	20.0
1.25	1	6	7	9.3	12.0
Total	14	61	75	100	100

The students' selected responses after computing and thinking for the third question which asked to examine the motion of a vehicle (a lorry) moving with constant velocity (without acceleration) along a straight line in the same direction and another vehicle (a bus) moving and slowing down with constant acceleration were presented in Table 3. Although the correct answer (1 m/s^2) was chosen by only 29.3% of the students, it is interesting that the predictions of the instructors who taught them linear motion for this response was 50.0%. Considered from another perspective, the rate of the students who could not choose the correct answer was 70.7%; thus, the instructors predicted that this rate could be mostly 50.0%. It can be stated that the rate of the elementary education students who could examine thoroughly the motion of a vehicle moving without acceleration along a straight line in the same direction and another vehicle moving and slowing down with constant acceleration is quite low (29.3%).

3.4 Question 4

A lorry travelling with a constant velocity of 144 km/h passes a traffic patrol car waiting at the crossroads. The police car starts to chase the lorry with an acceleration of 2.5 m/s^2 at the moment the speeder passes the police car. Find the distance travelled from the crossroads by the police car to catch the lorry. Please calculate it.

Table 4: Elementary education students' responses related to the distance travelled by the police car to catch the lorry

Student Responses	Male	Female	Total	%	Instructors' Predictions (%)
Those who computed the distance travelled by the police car to catch the lorry correctly	2	6	8	10.7	40.0
Those who computed the time required for the police car to catch the lorry travelled by the police car to catch the lorry correctly	-	2	2	2.7	20.0
Those who could only write the vehicles' equations of motions correctly and equal to one another.	-	11	11	14.7	15.0
Those who could only write the vehicles' equations of motions correctly	-	4	4	5.3	10.0
Those who could only write one of the vehicle's equation of motion correctly	-	8	8	10.7	-
Those who only expressed the value of 144 km/h as 40 m/s	3	9	12	16.0	5.0
Those who wrote irrelevant or incorrect equations	4	11	15	20.0	-
Those who wrote any equation or explanation	5	10	15	20.0	10.0
Total	14	61	75	100	100

When Table 4 is examined, it is found that out of 75 elementary education students participating in the study, only 8 (10.7%) of them could compute the distance travelled by the police car to catch the lorry correctly, only 2 (2.7%) of them could compute the time required for the police car to catch the lorry correctly and only 11 (14.7%) of them could write the vehicles' equations of motion correctly and equal to one another. Because it is required that the units belonging to the data should be compatible with one another for the solution of the question, it draws attention that there were 53 (70.7%) students who could not express the value of 144 km/h as 40m/s. The findings also reveal that there are a total number of 30 (40.0%) students, 15 of those who wrote irrelevant or incorrect equations and 15 of those who wrote any equations or explanations and those students (30) could not suggest any correct explanations or equations for the solution of the problem. Because the rate of the students who left the question blank without writing any explanations and equations for the question was 20.0%, this could explain the reasons why multiple choice questions were used in the research and why there were three (3) multiple choice questions in contrast to one open-ended question.

It is also considered that the instructors who taught linear motion to elementary education student made predictions about the students who computed correctly the distance travelled by the police car to catch the lorry and their predictions were 40.0%, their predictions for those who left the question blank were 10.0% and they did not make any predictions for those who wrote irrelevant and incorrect equations.

4. Elementary Education Undergraduate Students' Views Stated During the Interviews

In addition to elementary education second year students' opinions taken about linear motion via an interview form consisting of three multiple-choice questions and one open-ended question, semi-structured interviews were carried out with 7 students who were randomly chosen from the population based on volunteerism and having spare time. Out of seven students' original views expressed about the same questions, four statements were chosen and presented below:

> *"I can say that all questions were difficult for me."*

> *"I believe I answered the multiple-choice questions correctly because I thought while choosing the answer and I made simple calculations. Moreover, for the open-ended question, that is the last question, I can say that I answered it correctly with the required explanations for the question because my peers and I discussed about its solution."*

> *"I chose the correct answers for the multiple choice questions upon thinking but I left the open-ended question blank."*

"I thought that I could solve the open-ended question, and I wrote the equations of motion for the lorry and traffic patrol car correctly and equal to one another but the result I got was quite different from those who said that they did it correctly. I do not remember where I made a calculation error."

5. Results, Discussion, and Recommendations

It is revealed in the study that out of the 75 elementary education undergraduate students participating in the study, 60.0% of them perceived average velocity and average speed as identical quantities, 66.7% of them could not compute the velocity of the car which starting from rest speeds up with constant acceleration at the end of the distance travelled correctly, and 70.7% of them could not compute the correct value of the acceleration of the vehicle moving with and slowing down with constant acceleration along a straight line. Considering the elementary education second year students' responses, the predictions of instructors who taught one dimensional motion to them were 40.0%, 40.0% and 50.0%, respectively.

It was also found that 89.3% of the students could not compute the distance travelled by another car starting from the rest and moving with a constant acceleration to catch the car travelling with a constant speed along a straight line in the same direction and although 56.0% of the students could not write one of the cars' equations of motion correctly, the instructors' predictions related to the responses of the students to this open-ended question were 40.0% and 15.0%, respectively.

The elementary education second grade undergraduate students' responses chosen and written for the questions about one dimensional motion and their opinions delivered in the semi-structured interviews reveal that they did not understand the topic of one dimensional motion at a desired level. It was regarded that the instructors' predictions made about the students' responses related to the questions about linear motion were considerably inaccurate and different the instructors' inaccurate predictions reveal that they do not have adequate information about their students' understanding levels of linear motion to whom they try to teach the quantities and equations about linear motion. The findings of some studies (Yıldız, Büyükkasap, Erkol & Dikel, 2007; Yıldız, Büyükkasap & Günel, 2011; Yıldız, 2016a; Yıldız, 2017a) support the findings determined/revealed about the second year undergraduate students' understanding levels of linear motion.

It is important to give the definitions of concepts and quantities, explain important-basic properties and examples teach equations at beginner level and solve many and different questions about linear motion in a general physics course designed for elementary education students. Without specifying that displacement and distance are different quantities and they have different properties, it is not easy and permanent for students to comprehend that average speed and average velocity are different quantities. The teaching order of quantities and choosing good examples related to them are important as is the case with teaching concepts.

Based on some quasi-experimental studies (Yıldız & Büyükkasap, 2011a; Yıldız, & Büyükkasap, 2011b; Yıldız, 2012a; Yıldız, 2012b; Yıldız, 2014b; Bozat & Yıldız, 2015; Yıldız, 2016b), it can be stated that writing to learn activities have positive effects on academic achievement of students studying at different levels. Elementary education undergraduate students can be asked to develop and write writing to learn activities for younger students or young adults in high schools while finishing the topic of one dimensional motion. The person who performs writing to learn activity acts with the intention of explaining the subject in a much simpler way. During the development process of a writing to learn activity (a letter, a summary, a diary, etc.), the student can learn the subject much better while thinking and making an effort to teach his students. In fact, the main purpose of writing to learn is to enable the writer to construct the subject s/he writes correctly and permanently in his mind.

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