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Pre-service Science Teachers' Understanding of One-Dimensional Motion Graphs in the Kinematic Context

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Abstract

The aim of this study is to examine pre-service science teachers' understanding of graphs in kinematic context. This study focuses on one-dimensional motion graphs. The participants in this study are 115 pre-service science teachers. The data of the study was gathered with an open-ended questionnaire. The case study approach was used in this study. The qualitative data is analysed using thematic content analysis. The results of this study reveal that more than half of the participants cannot adequately understand the one-dimensional motion graphs. These findings suggest that pre-service science teachers' instructors should be aware of their students' difficulties in understanding of kinematic graphs. Furthermore, teaching modules which will promote the pre-service science teachers' understanding of kinematic graphs are designed and implemented.

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Keywords: Interpretations of graphs, one-dimensional motion, kinematic, pre-service science teachers

1. Introduction

In the 21st century, individuals frequently are engaged in graphs in their daily life while reading newspapers, magazines, articles, watching TV news, and surfing on the net. Economic developments, election results, the results of public reports in the field of education and health and so on are presented by graphs. Therefore, graphing competence is important and crucial for all the citizens who often need it in their daily life beyond the school achievement. A set of publications and standards such as *Benchmarks for science literacy* (American Association for the Advancement of Science (AAAS), 1993), *Next Generation Science Standards* (National Research Council (NRC), 2013) suggest that students should be able to use graphs to analyse and interpret data, mathematics and computational thinking, engage in arguments from evidence and provide communication by the end of the 12th grade.

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If we want the students to understand graphs, the teachers are required to acquire the graph interpretation skills (Jocobbe and Horton, 2010). Kinematic is the branch of mechanics which describes the motion of a body or a system of bodies without consideration given to its mass or the forces acting on it. Graphs are commonly used in the kinematic context. Generally, variables of kinematic-position, velocity and acceleration-are represented in the graphs. However, students have troubles with the kinematic graphs (Hale, 2000). One-dimensional motion is motion along a straight line with constant or changing velocity. The one-dimensional motion is a starting point for kinematic courses. It might be beneficial to search how pre-service science teachers who are going to teach science to the students at primary education level understand one-dimensional motion graphs.

1.1 Aim

The aim of this study is to examine the pre-service science teachers' understanding of one-dimensional motion graphs in kinematic context. The guiding research questions were:

- What is the understanding of pre-service science teachers about velocity-time graphs of one-dimensional motion in the kinematic context?
- What is the understanding of pre-service science teachers about position-time graphs in one-dimensional motion in the kinematic context?

2. Method

The case study approach, a form of qualitative research method was used in this study (Noor, 2008). The participants in the study were 115 pre-service science teachers. They are in first year in their teacher training program. 70 of the participants were females. The data of the study gathered with an open-ended questionnaire. The questionnaire includes two graphs of one-dimensional motion in kinematic context. One of the graphs is a velocity-time graph and there are four questions relating to this graph. The other graph is a position-time graph and there are five questions relating to this graph. The questionnaire was examined by an expert group which consists of three experts. Except the sampling of the study, the questionnaire was piloted with a group of 36 pre-service science teachers. According to feedback obtained from expert group reviews and piloting, necessary revisions were made. Appendix presents the questionnaire. The qualitative data were analysed using thematic content analysis (Braun and Clarke, 2006). While the data were analysed in the study, firstly the responses of the participants to each question in the questionnaire were coded. Then themes and sub-themes were composed. Frequency and percentages were calculated for each sub-theme. The data were analyzed independently by the author of the paper and a physics instructor. The small differences (less than 5%) between the two coders were agreed via negotiations.

3. Results

3.1 Pre-service Science Teachers' Understanding of Velocity-Time Graphs of One Dimensional Motion in the Kinematic Context

Table 1 presents the findings obtained from the responses of the pre-service science teachers to the questions in velocity-time graph. Less than a quarter of the pre-service science teachers' responses fell into sound understanding theme (from 1% to 15%) for velocity-time graph. Most of the pre-service science teachers had partially understanding for velocity-time graphs. More than half of the pre service science teachers could not understand velocity-time graph when the velocity-time graph showed a line with a negative slope.

Table 1 Pre-service Science Teachers' Understanding of Velocity-Time Graph

Question	Themes	Sub themes	f	%
Question 1	Sound understanding	Constant positive acceleration	5	4
		Motion in a positive direction	18	16
	Partial understanding	Increasing velocity	79	69

		Object moves	3	3
		Increasing acceleration	2	2
	No understanding	Constant velocity	6	5
		I don't know	2	2
Question 2	Sound understanding	Constant velocity in a positive direction	7	6
	Partial understanding	Constant velocity	94	82
		Stationary	5	4
	No understanding	Constant acceleration	5	4
		I don't know	4	3
Question 3	Sound understanding	Decreasing velocity in a positive direction	1	1
	Partial understanding	Decreasing velocity	39	34
		Motion in a negative direction	56	49
		Stationary	11	10
	No understanding	Constant velocity	4	3
		Decreasing acceleration	4	3
		I don't know	0	0
Question 4	Sound understanding	Constant negative acceleration	17	15
	Partially understanding	Motion in a negative direction	36	31
		Increasing velocity	13	11
		Decreasing velocity	16	14
		Mathematically, the value of velocity is negative	12	10
	No understanding	Stationary	9	8
		Constant velocity	9	8
		I don't know	3	3

2.2 Pre-service Science Teachers' Understanding of Position-Time Graphs of One Dimensional Motion in the Kinematic Context

Table 2 presents the findings obtained from the responses of the pre-service science teachers to the questions in position-time graph. The position-time graph includes five questions in the questionnaire. Only 10% of the pre-service science teachers' responses fell into the sound understanding theme for the three questions. Most of the pre-service science teachers' responses fell in to the no understanding theme for the position-time graph.

Table 2 Pre-service Science Teachers' Understanding of Position-Time Graph

Question	Themes	Sub themes	f	%
Question 1	Sound understanding	Increasing velocity in a positive direction	13	11
	Partially understanding	Motion in a positive direction	7	6
		Object changes position	66	57
		Constant velocity	3	3
		Decreasing velocity	4	3
	No understanding	Object rises	8	7
		Increasing acceleration	2	2
		I don't know	12	10
Question 2	Sound understanding	Decreasing velocity in a positive direction	10	9
	Partially understanding	Decreasing velocity	32	28
		Increasing velocity	31	27
		Object rises	4	3
	No understanding	Object falls down	4	3
		Increasing velocity in a negative direction	4	3
		Constant velocity	4	3

		Maximum velocity	3	3
		Object slows down at a constant velocity	5	4
		I don't know	18	16
Question 3	Sound understanding	Stationary	52	45
		Constant velocity	53	46
		Constant acceleration	2	2
	No understanding	Maximum velocity	2	2
		Decreasing velocity	2	2
		I don't know	4	3
Question 4	Sound understanding	Increasing velocity in a negative direction	19	17
	Partial understanding	Motion in a negative direction	12	10
		Decreasing velocity	52	45
	No understanding	Object slows down at a constant velocity	10	9
		Object falls down	17	15
		I don't know	5	4
Question 5	Sound understanding	Constant velocity in a negative direction	9	8
	Partial understanding	Constant velocity	14	12
		Decreasing velocity	38	33
		Decreasing velocity in a negative direction	5	4
		Increasing velocity in a negative direction	7	6
	No understanding	Object slows down at a constant velocity	8	7
		Stationary	11	10
		Object falls down	16	14
		I don't know	7	6

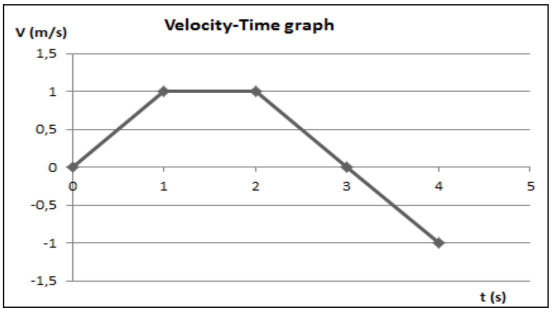
4. Discussion and Conclusion

The results of this study reveal that less than half of the participants can adequately understand the one-dimensional motion graphs in kinetic context. Pre-service science teachers usually understand one-dimensional motion graphs partially. They are not able to make explanations about acceleration and position depending on the velocity-time graph. This result might depend on various reasons. One of the reasons is that it is not an easy task to go beyond the direct data on the graph because it requires high level cognitive skills (Aoyama, 2007; Jacobbe and Horton, 2010). Learners need the support of the instructors in order to overcome these tasks. The results of the study suggest that pre-service science teachers compose their unscientific concepts by assembling different concepts in the kinematic context. For example, object slows down at a constant velocity is such a concept. This condition might imply that pre-service science teachers do not understand kinematic concepts in depth. Another reason for the lack of pre-service teachers' adequately understanding of one-dimensional motion graphs is that they might have weak pre knowledge about the concepts in kinematic context. As it is emphasized in literature, the learners should be familiar with the context of the graph in order to understand the graphs (Roth, 2004; Wemyss and Kampen, 2013). Another result obtained from the study is that pre-service science teachers read one-dimensional motion graphs as if they are pictures. Learners' reading the graphs as pictures is a common cognitive error (Glazer, 2011). The main reason for this situation might be the learners' weak view points to the nature of graphs.

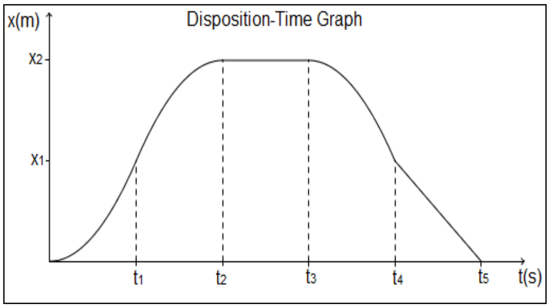
5. Suggestions

The importance of graphing competence has been understood very well in educational context. The studies conducted reveal that the students do not acquire graphing competence at an intended level. Graphing competence is not an easy task. Students cannot learn to cope with this task on their own. If we want the students to understand graphs, the teachers are required to acquire the graphing competence. The freshman pre-service teachers do not adequately understand the basic graphs of kinematic context. Pre-service science teachers' instructors should be aware of their students' difficulties in understanding of kinematic graphs. Furthermore, they should design and implement various teaching modules to promote pre-service science teachers' understanding of kinematic graphs. This study was carried out with only freshman pre service science teachers. In the future studies, freshman and senior pre-service science teachers' understanding of kinematic graphs may be compared.

Appendix



1. Explain the motion of the object between the 0st and 1nd second.
2. Explain the motion of the object between the 1nd and 2rd seconds.
3. Explain the motion of the object between the 2rd and 3th seconds.
4. Explain the motion of the object between the 3th and 4th seconds.



1. Explain the motion of the object between the 0-t_1 seconds.
2. Explain the motion of the object between the t_1-t_2 seconds.
3. Explain the motion of the object between the t_2-t_3 seconds.
4. Explain the motion of the object between the t_3-t_4 seconds.
5. Explain the motion of the object between the t_4-t_5 seconds.

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