Influence of a motion sensor on the understanding of graphs

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Various technological tools have been used for improving science teaching and learning, but using it in a productive manner to improve the quality of learning is not easy. The aim of this study was to determine the influence of the go motion on the understanding of kinematic graphs by firstly evaluating the materials to establish if it is suitable for technology-supported inquiry activities and secondly determine if the frequent graphing misconceptions has been addressed. A single instructional experience utilizing the research-based tutorial materials is superior to a traditional quantitative laboratory experience for conceptual understanding and because this study was done during one lab session the third goal of this study was to find out if one lab can make a difference. The activities were evaluated using the Learning-for-Use (LfU) model and TUG-K was used as pre and post test. The class average increased with 13%. Data from the completed worksheets of the activities as well as the reasoning on the pre- and post tests were analysed to alleviate the confusion or conceptual understanding of the slope and height of lines, the areas under graphed curves and the symbolic representation of information.

Introduction

The use of technology is becoming a powerful component of science teaching (Papdouris & Constantinos, 2009). Various technological tools have been used for improving science teaching and learning (Caner & Ogan-Bekiroglu, 2009). However, the integration of computer-based tools with science learning in a constructive manner to improve the quality of learning is not easy (Ainsworth *et al*, 1998). In order to enhance learning, special care should be taken to ensure productive integration with curriculum materials (Papdouris & Constantinos, 2009). For this reason, the learning for use – framework was used to evaluate if the materials used for this study were suitable for technology-supported inquiry activities (Edelson, 2001).

Students have consistent difficulties with the interpretation of kinematics graphs – i.e. graphs of position, velocity or acceleration versus time (Mc Dermott *et al*., 1987, van Zee & Mc Dermott, 1987 and Beichner, 1994). The most frequent graphing misconceptions seems to be confusion between the slope and height of lines on the graphs (Mokros & Tinker, 1987 and Barclay, 1986), the tendency to see the graph as a picture rather than as a symbolic representation of information and lastly they do not understand the meaning of the areas under graphed curves (Beichner, 1996).

The understanding of graphs can be effective if MBL (micro based laboratory) activities are used (Barclay 1986, Mokros, 1986 and Thornton 1986). In this study a go motion was used in conjunction with a computer. A go motion allows immediate real-time data collection, provides graphical representation of the collected data and is not complicated. It is fast and dynamic and provides genuine scientific experiences that could motivate and encourage students (Brasell, 1987). Learners have the opportunity to reshape their original hypotheses, test new hypotheses and display new results (Friedler *et al*., 1990).

In addition, learners have more time to analyse and interpret data (Mokros & Tinker, 1987; Thornton & Sokoloff, 1990) and give more opportunities for problem solving, critical thinking and reflection (Casey, 2001).

The aim of the study is to determine the influence of the go motion on the understanding of kinematic graphs.

Reason for study

There is a constant debate if "old school" lab techniques (e.g., ticker tape timers, graphing by hand, etc) and "new school" lab techniques (e.g., motion detectors, graphing by computer, etc.) have the best effect on student understanding and achievement. An argument in favour of the old school is that seeing the data as physical dots makes the motion much easier to understand and the graphs then have something physical to compare to. If students have to draw the graphs by hand they learn that plotting data is not easy (Noschese, 2009). While an argument to support the new school is that ticker-tape experiments in high school is a big blur of tedious repetitive measurements with no connection whatsoever to the significance of the dot spacing – it only learn how mind-numbingly tedious and frustrating experimental work can be (Wagner, 2009).

However, the real issue isn't whether the equipment is high-tech or low-tech, new school vs. old school, the real issue is how well the pedagogical approach addresses the learning goals and what approaches the equipment supports and doesn't support. If the goal is to help students understand the mechanics of a graph, there is nothing like drawing the graph by hand. If the goal is to have a gut feeling of what a velocity plot means, few things can beat it being drawn in real time while the student is moving their body back and forth. It is not the tool; it is what is done with it (Bonham, 2009).

The goal of this study was to determine the influence of the go motion on the understanding of kinematic graphs by firstly evaluating the materials to establish if it is suitable for technology-supported inquiry activities and secondly determine if the frequent graphing misconceptions has been addressed.

Abbott, *et al*, (2000) found that a single instructional experience utilizing the research-based tutorial materials is superior to a traditional quantitative laboratory experience for conceptual understanding and because this study was done during one lab session the third goal of this study was to find out if one lab can make a difference.

Framework: Learning-for-Use (LfU)

The Learning-for-Use (LfU) model is a design framework that was developed to support the design of learning activities that achieve both content and process learning (Edelson, 2001). In this study it was used to evaluate two of the activities (M.1 and M.2) compiled by TRAC South Africa on mechanics to determine if it has promoted conceptual understanding of graphs by applying it in a different context.

The LfU incorporates four principles that are shared with many contemporary theories of learning. They are: learning takes place through construction and modification of knowledge structures; it is a goal directed process; circumstances are important and have to be constructed in a form that supports use before it can be applied. The model characterizes the development of useable understanding as a three-step process consisting of motivation, knowledge construction and knowledge refinement (Edelson, 2001).

Motivation in this model refers to the motivation to acquire specific skills or knowledge within a setting in which the student is already reasonably engaged. Knowledge construction is the development of a new knowledge structure in memory that can be linked to existing knowledge while knowledge refinement responds to the need for accessibility and applicability in learning for use. To be useful, declarative knowledge must be reorganized into a procedural form that supports the application of that knowledge (Anderson, 1983, cited in Edelson, 2001).

Sample

Data was collected in 2009 at one school in the Tshwane North District of the Gauteng region after the topic mechanics was dealt with during class time. An open invitation was given to all physical science grade 10 learners (194). Only 5 learners were prepared to participate in the research.

Methodology and data collection

LfU model was used to evaluate two of the technology-supported inquiry activities (M.1 and M.2) using the three step process and the completed worksheets were also analysed to alleviate the misconceptions regarding graphs. The Test of Understanding Graphs – Kinematics (TUG-K) test was used as the pre test (Beicher, 1996). The aim of the pre-test was to elicit conceptual problems and this was done by asking the learners to explain each of their answers. Their prior knowledge was taken into consideration during the lab session. The lab session was conducted one afternoon for 2 hours. Learners were given the opportunity to use the motion sensor to draw position-time (s-t), velocity-time (v-t) and acceleration-time (a-t) graphs, analyse and interpret them. After the intervention the same test was given 3 days later as a post-test and again had to explain their answers. The students wrote their end of year examination 1 month after the intervention and the question on graphs were analysed.

Data from the completed worksheets as well as the reasoning on both the tests were analysed to alleviate the confusion or conceptual understanding of the slope and height of lines, the areas under graphed curves and the symbolic representation of information.

Findings

Evaluation of technology-supported inquiry activities

Two of the mechanics Trac SA activities were evaluated using the three step process of the LfU model. These activities were specially designed with theory, learning outcomes, and assessment standard according to the National Curriculum Statement (DOE, 2001). The first activity (M.1) was on reference points and directions while the second activity (M.2) was on the relationship between the motion graphs of uniform accelerated motion.

Table 1 describes the different processes that fulfil the requirements of each of the 3 steps. The first column represent the 3 steps to be followed, the second column describe the 2 processes necessary for that step, while the third column describes activities that teachers can use to achieve the steps in the LfU model. The forth column indicate how this was done with M.1 and M.2

Table 1: Application of the LfU model

Step	**Process**	**Design Strategy**	**Application**	
		Activities that	M.1	M.2
Motivate	Experience demand	Create a demand for knowledge	Practical application of an aircraft that is guided towards touchdown by constant measurement of the motion with respect to the runway	Practical application by providing a map of SA and explaining the difference between average and instantaneous speed and average velocity
	Experience curiosity	Elicit curiosity	Not done	Not done
Construct	Observe	Provide direct experience	Procedural on how to prepare for the experiment with aims, equipment needed precautions and procedures to execute the exp.	Same as M.1 and predict and draw a graph for a ball that is released at the top of an incline, then describe and provide a reason for s-t, v-t and a-t graphs
	Receive communication	Provide direct or indirect communication	Different graphs were given and students had to simulate the motion and give a description. Answers were discussed.	Table on gradients had to be completed, questions answered and discussed.
Refine	Apply	Apply knowledge	Simulate a described motion and then draw a graph	Simulate a described motion and answer questions and draw an a-t from a v-t graph
	Reflect	Provide reflection	A graph of a moving object is presented. They had to simulate the displacement and	Had to compare their graphs with their predictions

			answer questions	

All three steps were followed in the design of these activities; the only process that was not specifically addressed was to elicit curiosity of the topic.

Evaluation of Pre-and Post-tests and Worksheets

The TUG-K test (pre- and post-tests average 58.1% and 71.4%) and the M.1 and M.2 activities (average 73% and 66%) were categorised to determine which questions are related to the 3 conceptual difficulties normally experienced when doing graphs. They are the slope and height of lines, the areas under graphed curves and the symbolic representation of the information.

Slope and height of lines

The answers to the pre- and post test of selected questions on the TUG-K test regarding the slope and height of lines are presented in table 2.

Table 2: Results of pre-and post tests with regards to the slope and height of lines

Question	**Pre test**	**Post test**
2	60	80
3	100	100
5	60	80
6	40	60
7	40	40
11	**40**	**100**
12	80	100
13	80	80
14	80	100
17	60	60
19	**40**	**80**
Average	**62**	**80**

In Question 11 a s-t graph was given and the learners had to choose which of the 5 v-t graphs would best represent the object's motion during the same time interval. During the first activity (M.1) in the lab the students had to simulate the motion presented in the different given s-t graphs as well as to calculate the slopes of these graphs (See table 3 on M.1). This could have had a direct effect on the answering of question 11 in the post test.

In Question 19, one s-t, 2 v-t and 2 a-t graphs were given. The candidates had to choose which of these graphs represent motion at constant, non-zero acceleration. In the second activity (M.2) students had to predict s-t, v-t and a-t graphs of various motions with a ball. They had to do the activity, compare gradients and shapes of the graphs and then reflect on their predicted graphs. This is not an easy activity as seen how they have scored on the selected questions in table 3 on M.2. However, by doing these activities in the lab could have had a direct effect on the answering of question 19 in the post test.

Table 3: Results of worksheets with regards to the slope and height of lines

M.1			M.2		
Question	**Of total**	**Average of class**	**Question**	**Of total**	**Average of class**
1.1-1.6		85	1.2		100
2.1 - 2.3	44%	87	3.2	14%	13
3.2-3.3		92			
		87			**57**

Areas under graphed curves

The answers to the pre- and post test of selected questions on the TUG-K test regarding the areas under graphed curves are presented in table 4.

Table 4: Results of pre-and post tests with regards to areas under graphs

Question	Pre test	Post test
1	**0**	**40**
4	**60**	**100**
10	60	60
15	80	100
16	80	80
18	100	100
	63	**80**

Different v-t graphs for five objects were shown in question 1. All axes had the same scale. The candidates had to indicate which object had the greatest change in position during the interval. In M.2 the participants had to simulate a motion on the computer by using a ball, of a car parked in the driveway that pulls away, accelerates for a few seconds, and maintains its velocity and then brakes as it approaches the garage. In the garage the car comes to a rest for a while and then immediately accelerates in reverse. The car then maintains its velocity for a few seconds before it finally comes to rest in the driveway again. One of the questions asked was to calculate the total distance travelled by the car. This question was answered without any difficulty as seen in table 5 on M.2.

In question 4 a v-t graph was shown of an elevator moving from the basement to the 10th floor of a building. The learners had to indicate how far the car moved during a certain time interval. The increase between the pre and post could be as a result of the explained activity in M.2.

Table 5: Results of worksheets with regards to areas under graphs

M.1			M.2		
Question	**Of total**	**Average of class**	**Question**	**Of total**	**Average of class**
0			3.3	29%	100

Symbolic representation of information
The answers to the pre- and post test of selected questions on the TUG-K test regarding the symbolic representation of information in table 6.

Table 6: Results of pre-and post tests with regards to the symbolic representation of information

Question	Pre test	Post test
8	60	80
9	40	60
20	80	80
21	0	20
	45	**60**

A s-t graph of an object's motion was given in question 8 and the learners had to select the sentence which gave the correct interpretation. Five different s-t graphs of an object's motion were presented in question 9 and they had to choose which of the 5 graphs correctly describes the situation. Although there was an increase in the learners' performance on these 2 questions the learners had difficulty in drawing a graph in question 2.4.1 of M.1 to illustrate the difference between (a) a slow and fast moving object, towards the reference point in a direction away from the sensor, and (b) a stationary object on the negative side of the reference point and a moving object away from the reference point in a direction towards the sensor. Not one student could draw the graphs correct. They also had difficulty in explaining the displacement and velocity over each section that was presented by a s-t graph in question 3.4 of activity M.2. This is in agreement of what was found by Beichner (1996).

The most difficult question was question 21. The learners only managed a score of 20%. A v-t graph was presented and they had to indicate which sentence gave the best interpretation. Because they did not score well I interviewed 3 of the 5 learners. All of them indicated that they haven't dealt with acceleration which is not constant. They must have misinterpreted the question, because although the slope of the v-t graph was negative, it still represents constant acceleration.

Table 7: Results of worksheets with regards to symbolic representation of information

M.1			**M.2**		
Question	**Of total**	**Average of class**	**Question**	**Of total**	**Average of class**
2.4.1		20	1.1 & 1.3		90
3.1	56%	56	3.1	57%	55
		38	3.4		40
					62.5

A month after the lab session the learners wrote the end of year exams. Question 2 was on graphs and counted 22 of the 150. After analysis of the question, nothing was found worth mentioning. An average of 86% was obtained for this question for the 5 learners participating in the research.

Conclusion

The LfU model characterizes the development of useable understanding as a three-step process and after evaluating the technology-supported inquiry activities it was found that all the steps were addressed. The use of the go motion detector had positive effects on the students' understanding of graphs with particular reference to the understanding of the slope and height of lines, the areas under graphed curves and the symbolic representation of information. These results are consistent with the results presented by Mokros & Tinker, (1998), Svec (1995) and Caner & Ogan-Bekiroglu, (2009). In addition I would like to concur with Abbott, *et al*, (2000) that one lab session indeed makes a difference!

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