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PROSPECTIVE SCIENCE TEACHERS UNDERSTANDING OF KINEMATIC GRAPHS IN COLLABORATIVE SOCRATIC QUESTIONING COURSE ACCOMPANIED BY WEB-BASED FORMATIVE ASSESSMENT

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Abstract. Projectile motion is still a challenging subject matter for students. So far, efforts to improve understanding of the concept have not optimally involved formative assessment. In this study, an analysis was carried out to investigate prospective science teachers' understanding of one-dimensional kinematic graphs as the effect of collaborative Socratic questioning course accompanied by web-based formative assessment. The embedded experimental research involved 30 students consisting 5 men and 27 women. Quantitative data were obtained from pre-test and post-test that utilize multiple choice tests with reasons. Qualitative data were obtained from classroom learning activities, reasons of student answers, e-learning, and interviews. Based on the N-gain value (0.31), it can be seen that collaborative Socratic questioning accompanied by web-based formative assessment increase the kinematic graphs concepts in the medium category. Based on the D-effect size value (1.41), course has a strong influence on the concept of students' kinematic graphs. However, it was found that there are still some student difficulties in determining the displacement of the time velocity graphs and the velocity of time acceleration graphs. Collaborative Socratic questioning learning accompanied by web based formative assessment can be an alternative to help students' kinematic graphs material.

Keywords: collaborative Socratic questioning; web-based formative assessment; concept of kinematic graphs

Introduction

One of the difficulties for students in kinematic learning is how to interpret kinematic graphs. Students have difficulties to interpret the relationship between position of speed, and acceleration of time in straight motion of the graph (Bollen et al., 2016; Erceg & Aviani, 2014; Hale, 2000; Zavala et al., 2017). First semester students succeeded to make the graphs with appropriate lines, but they cannot connect the graphs with meaning to the underlying physical concepts (Nixon et al., 2016). Lack of mathematical knowledge is not the main reason for students' difficulties of kinematic graphs, but interpretation of the meaning of slope graphs in the context of physics which presents the biggest problem for students (Planinic et al., 2012). Students experienced great difficulty in the concept of the graph area below. Kinematic graphs remains a difficult context for most students even though they have learned kinematic graphs at secondary school level (Planinic et al., 2013).

Various attempts were made to overcome students' difficulties about kinematic graphs. Efforts included encouraging students to carry out activities in physics laboratories (Nixon et al., 2016), a multi-representation approach, computer tutors (Kane & Sherwood, 1980), using digital video about motion (Beichner, 1996; Larkin-Hein & Zollman, 2000), and computational models (Araujo et al., 2008). Students construct and interpret graphs in order to connect laboratory procedures with a comprehension which is related to physics concepts (Nixon et al., 2016). With kinematic graphs, interactive videos can improve students' understanding and motivation. (Larkin-Hein & Zollman, 2000). Besides that, mastering the concept of kinematic graphics requires special studying to explore difficulties to correct them effectively.

In the last few years, students' conceptual understanding in science was sought after in researches. It is very important for physics teachers to investigate students' misconceptions about certain physics concepts and design an appropriate teaching method to resolve changes in students' conceptual frameworks (Jiang et al., 2018). Two students who work together use different categories of knowledge and build different conceptual meanings (Küçüközer, 2006). The climate and culture of school organizations are fun and constantly sustain teachers so that they work energetically to improve their work (Gemnafle et al., 2016). Some alternative concepts are still maintained by students in the experimental group. Teachers have similar alternative concepts and difficulties. Radical changes are needed in the design of teaching physics if we want to improve students' conceptual understanding (Başer, 2006).

All learning is in the art of asking. Asking is the basic of teaching tasks that encourage memory, depending on the learning process, understanding, increasing imagination, problem solving, fulfilling curiosity, and increasing creativity (Zolfaghari et al., 2011). One of the main goals of education is to develop critical and creative thinking, which can be achieved by in-depth learning called question and answer (Albergaria-Almeida, 2010b). The Socrates method is important to show metacognitive regulations (Thompson et al., 2016). Socratic dialogue increases sensitivity between teachers and students when it is time to encourage the understanding of concepts (Knezic et al., 2010). Asking questions are also a way to evaluate students' knowledge, improve their understanding, and stimulate their critical thinking. Lack of questions and answers can deactivate learning by creating confusion, intimidating students, and limitations in creative thinking (Tofade et al., 2013). A teacher maintains the rules as a facilitator who is active during the process of Socratic questioning (Boa et al., 2018). A collaborative questioning is used to generate convergence among learning assignments, class interactions, and learning outcomes (Ng'ambi, 2006a). Collaboration with prospective teachers can increase their pedagogical knowledge (Milner-Bolotin et al., 2016). In teaching, a series of professional development programs about the integration of culture and language in scientific teaching can be operated for experimental processes on aspects of teaching (Morales, 2016).

Students do not ask questions and have little interaction during face-to-face classes. Online media facilitates conceptual questions posed by teachers to generate and receive feedback and improve further questions. Technological developments have created a breakthrough in learning. In the process of development, students often contact cellular and internet communication devices into new trends that have the possibility to regulate learning (Astra et al., 2015). Technology creates a different social regime when used by several people in asking questions, resulting in continuous interaction where members comment on something posted by one of them (Rughiniş et al., 2014). Collaborative Socratic questioning is a learning method which is useful and has more power by applying the web in it (Ng'ambi, 2006a). Collaborative Socratic questioning used in technology can provide a convergence of learning tasks, interactions and learning outcomes by accompanying students' mobility, where students can engage with tasks that require them to think critically, ask questions, and respond to questions (Ng'ambi, 2006b).

Sometimes, assessments in learning are not used to improve learning. Formative assessment must encourage and support the learning process, provide effective feedback, and be responsive to the way students learn to develop the essence of learning. Student directed activities can facilitate the development of abilities accompanied by feedback from other students and themselves (Valdez et al., 2014). The five key formative assessments and collaborative Socratic questioning are easy to implement by using computer technology or gadgets owned by educators and students. Formative assessments can be explored as optional additions to improve students' performance in higher academic abilities (Mitra & Barua, 2015). Interactive online formative assessment can improve the overall learning experience of students (Bijol et al., 2015). The report contains important information for students and teachers to evaluate students' challenges and achievements (Kusairi et al., 2014). Theory-Technology Alignment Framework is the robustness and integrity of the design and implementation of digital education programs (Bajpai et al., 2019). Formative assessment assisted by computers is a valid instrument for diagnosing students' understanding of concepts in well-structured declarative knowledge (Maier et al., 2016). The web-based diagnostic test is a new alternative for physics teachers and researchers to identify students' misconceptions and error patterns (Kusairi et al., 2017).

The purpose of this study was to analyse prospective science teachers' understanding of one-dimensional kinematic graphs and find out the difficulties experienced by students after a collaborative Socratic questioning learning along with web-based formative assessment.

Method

This study uses mixed methods with embedded experimental design (Creswell, 2007). Research was conducted on one class of prospective science teachers who took basic Physics Course I at Malang State University. The concept mastery test instrument used in the form of 20 reasoned multiple choice questions that have high reliability of 0.747 and was categorized as valid for each item. The instruments with seven mastering indicators of the concept of one-dimensional kinematic charts are listed in Table 1.

Table 1. Learning indicators

No.	Indicators	Question Number
1	determine the speed of the position-time of graph	4
2	determine the acceleration of the speed-time of graph	2, 7
3	determine the displacement of the speed-time of graph	6, 16
4	determine the change in speed of the acceleration-time of graph	9, 19
5	choose another graph that is similar/ compatible from one kinematic graphs	11, 14, 18
6	choose text description from a kinematic graphs	5, 8, 12, 15, 17
7	choose a graph that is similar to text description of motion	1, 3, 10, 13, 20

The response was assessed by giving a score 2 for the choice of right answer with the right reason, score 1 for the choice of the right answer with the wrong reason, score 1 for the choice of the wrong answer with the right reason, and score 0 for the wrong answer choice with the wrong reason.

Interventions were carried out to apply collaborative Socratic questioning learning accompanied by web-based formative assessment. Collaborative Socratic questioning is taught by giving structured problems along with questions of Socrates, quizzes, and presentations. Web-based formative assessment was conducted by students prior to the start of lectures by opening e-learning at the State University of Malang which contains discussion forums, power points, and quizzes as a learning material. Interviews with semi-structured questions were conducted to determine students' difficulties and weaknesses during the intervention process.

N-Gain was done to find out how students' understanding of concepts were increased based on the results of the pre-test and post-test. The normalized gain score criteria (G) are shown in Table 2.

Table 2. Gain score normal criteria

Score	Criteria
G < 0,3 0,3 ≤ G < 7 G ≥ 0,7	Low Medium High

Hake, 1998

D-effect size was also used to find out the influence of intervention. The following are the criteria and effect size values listed in Table 3.

Table 3. Criteria of D-effect size

Range	Criteria
0 – 0,20 0,21 – 0,50 0,51 – 1,00 > 1,00	Weak effect Medium effect Enough effect Strong effect

Cohen & Swerdlik, 2007

Results

The values of the pre-test and post-test are shown in Table 4.

Table 4. Descriptive statistical grade of pre-test and post-test of students' understanding concept

Statistical Elements	Pre-test	Post-test
Mean	21,09	45,57
Standard Deviation	14,29	24,16
Maximum	57,5	100
Minimum	5,00	10,00

Table 4. shows that the average value of the pre-test and post-test has increased. An increase in students' understanding of the concept is discerned from the N-Gain value. The effect of collaborative Socratic questioning learning along with web-based formative assessment is known from the D-effect size value. The results of data analysis on understanding of students' concepts are presented in Table 5.

Table 5. Results of data analysis of student concepts

Analysis Data	Post-test – Pre-test
N-gain	0,31
Effect size	1,41

The calculation of the increases in the average value through N-Gain obtained a value of 0.31 which is in the medium category based on Table 2. While the D-effect size has strong effect, criteria based on Table 3. with the value of 1.41. It can be concluded that collaborative Socratic questioning learning accompanied by web-based formative assessment has a strong influence to improve students' comprehension of the concept of one-dimensional kinematic charts.

The percentage of students' answers to each indicator is shown in Table 6.

Table 6. Percentage of students' answers

Indicator	Percentage (%)							
	CC		CI		IC		II	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
determine the speed of the position-time of graph	6	50	19	13	-	25	75	13
determine the acceleration of the speed-time of graph	36	42	6	5	5	14	53	39
determine the displacement of the speed-time of graph	5	47	9	3	2	19	84	31
determine the change of speed in the acceleration-time of graph	11	19	5	9	2	-	83	72
choose another graph that is similar/ compatible to one kinematic graphs	6	25	17	9	1	16	76	50
choose text description from a kinematic graphs	15	48	14	11	5	9	66	33
choose a graph that is similar with the text description of motion	14	42	10	4	3	10	73	44

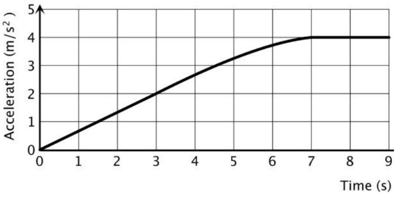
Description: CC = Correct choice Correct reason; CI = Correct choice Incorrect reason; IC = Incorrect choice Correct reason; II = Incorrect choice Incorrect reason

Students' understanding is said to be good if students can choose the answer correctly and give the right reasons. Table 6 shows that there is an increase of choice of right answers with right reasons for each indicator, and there is a decrease of choice of wrong answers with wrong reasons for each indicator. This indicates that students are increasingly mastering the concept of one-dimensional kinematics which is represented through graphics after experiencing collaborative Socratic questioning learning along with web-based formative assessment.

A decrease in percentage of the correct answer with the wrong reason indicates that some students have used the right method or given the right reasons to solve the problem before choosing the right answer. Even though that is good, students will not get the maximum score, because they provide the right reasons, but they chose the wrong answer and vice-versa.

The indicator determines the change of speed from the graph of the acceleration-time. A relationship should be discussed more deeply because it gives different results from the indicators in Table 6. This indicator is discussed by displaying one of the students' questions and answers in Table 7.

Table 7. The percentage of students' answers on the indicator determines the change in speed of the acceleration-time relationship graph



Problem
Susi cycles to north according to the graph of the relationship of acceleration to the following time. The change in the speed of the bicycle that Susi paddled in the first three seconds was ….

Choice of Answers	Pre-test (%)	Post-test (%)
1,5 m/s to the north	9,375	6,25
0,67 m/s to the north	18,75	18,75
2,0 m/s to the south	6,25	0
3,0 m/s to the north *	12,5	25
6,0 m/s to the south	43,75	46,875
Missing	9,375	3,125

* Key answer

Table 7 shows that there is a decrease in the percentage of answers in choice option (A), option (C), and there is no answer (blank) which is the wrong choice of answers. However, there is an increase of the percentage of answers in option (D) which is the correct answer. This is good, but a constant percentage on option (B) and an increase in percentage on option (E) is a negative matter. The model of reason given by students in the answer choice option (B), option (D) and option (E) is shown in Fig. 1.

1st Model	2nd Model	3th Model	4th Model
$v = \frac{\Delta a}{\Delta t} = \frac{2}{3} = 0{,}67\ m/s$	$v_t^2 = v_o^2 + \frac{1}{2}.a.t = 0^2 + \frac{1}{2}.2.3 = 3\ m/s$	$\Delta v = a.\Delta t =$ area under graph $= \frac{2 \times 3}{2} = 3\ m/s$	$\Delta v = a.\Delta t = 2 \times 3 = 6\ m/s$

Notes: 1st Model = reasons of (B) choice; 2nd Model = wrong reasons of (D) choice; Model III = correct reasons of (D) choice; and Model IV = reasons of (E) choice.

Figure 1. Students reason models

1st Model and 2nd Model in Fig. 1 show that students of origin in using mathematical equations adjusted for the numbers shown in the graphs. The mathematical equations used in 1st Model and 2nd Model do not correspond to the given questions, even though they get the value according to the provided answer of choices. The 3rd Model is the right solution for solving problems. This model provides the correct mathematical equation accompanied by the understanding of speed of the acceleration-time of graph that can be determined by calculating the area under the graph. However, the 4th model provides the correct mathematical equation, but not accompanied by proper understanding so students tend to multiply directly the values 2 and 3.

Discussion

The post-test results show that students' understanding of concepts were still low with an average of 40.87, even though students have studied collaborative Socratic questioning accompanied by web-based formative assessment. Many students were wrong in giving answers because questions have difficult categories. Some students obtained high and even perfect post-test scores as these students have a high mastering of concepts on one-dimensional kinematic charts after learning with collaborative Socratic questioning along with web-based formative assessment. The more difficult an item is, the higher ability of students who answered the question. Mapping the quality of questions at the level of Bloom's taxonomy cognitive domain will produce high quality questions (Bates et al., 2014).

Errors made by students in choosing answers or giving reasons indicate that students were still having difficulties in mastering the concept of one-dimensional kinematics which was represented through graphs. Difficulties in mastering this concept reappear when students focused more on mathematical equations than concepts that emerge, lack of logic in the relationship between both, and weak in recognizing the questions asked (Hashemi et al., 2014). Most students write mathematical equations without an explanation of the physical concepts contained in the problem. Students can solve the questions of graphs with mathematical equations without relating them to physics concepts (Nixon et al., 2016). Students tend to include values in the questions into mathematical equations without basing it on an appropriate concept, this is also called "plug and chug" in Docktor & Mestre (2014). Low values and wrong reasons caused by students working on questions with quantitative mathematical equations, while students who incorporate quantitative concepts or descriptions in mathematical equations tend to get high scores with the right choice of answers and reasons. This is in line with idea that successful problem solvers use qualitative representations to construct quantitative equations (Docktor & Mestre, 2014). Whereas problem solvers who are not successful, do not use representation or do not use it productively to solve problems.

Students' errors in using mathematical equations are caused by confusion in determining derivatives or integrals to solve problems. Students' confusion in determining gradients and regions in processing information contained in kinematic charts (Turner et al., 2014). Students find it difficult to understand the concept of derivatives as gradients and concepts anti derivative as areas below the graph (Planinic et al., 2013). In accordance with the study, many found solutions in the form of mathematical equations without using the concept of derivatives or anti derivatives, for example s = v.t and a = v / t.

Students who can answer questions correctly about speed can also answer questions correctly about acceleration (Lichtenberger et al., 2017). In determining the speed on the position-time of the graph and determining acceleration in the speed-time of the graph, students clearly provide solutions to graph gradients, using them explicitly or implicitly. However, the explicit or implicit ways lead them to different strategies of (using mathematical equations, wrong in this context) and do not activate their knowledge and reasoning (Planinic et al., 2013).

The most commonly found errors in students' answers were to determine the displacement on the time velocity of graph and determine the speed change in the time acceleration of the graph. The findings are consistent with the research result that students experience difficulties in determining the area under the graph (Nguyen & Rebello, 2011).

The acceleration experienced by objects at certain intervals is the same as the line gradient on the speed-time of the graph (Serway & Vuille, 2015). Changes in the speed of the acceleration-time of the graph can be determined by calculating the graph equation or the area below the graph. Table 7. shows that students experienced many errors during the pre-test and post-test in determining the speed change from the acceleration-time of graph. Students' errors to determine the displacement of the speed-time of graph are also found, although not as much as the indicators discussed in Table 6. Similarly found that students had difficulties to determine the area below the graph (Dominguez et al., 2017; Maries & Singh, 2013; Nguyen & Rebello, 2011; Planinic et al., 2013). Students tend to read numbers on the graph directly, namely number 2 on the y axis (acceleration) and number 3 on the x axis (time). The two numbers were then entered into a mathematical equation without understanding the physics concept of meaning of the equation so that the wrong answer was generated. The error was made by most of the students who chose answer D. Although the mathematical equation was correct, it produced the wrong value. They entered the number 2 as the acceleration value and number 3 as the time interval regardless of the sloping graph (acceleration increases). Students experience errors to determine the area of a rectangle, not the area of a triangle due to constant acceleration (Maries & Singh, 2013).

Qualitative descriptions as a support of the calculations made by students are only a few found. This is what causes a lot of mistakes produced by students during the pre-test and post-test. Successful problem solvers use qualitative representation to construct quantitative equations. Whereas problem solvers who are not successful, do not use representation or do not use it productively in solving problems (Docktor & Mestre, 2014).

The most widely used physics learning method in high school is the lecture method. Before the intervention, some students had experience doing problem exercises, while 13% of the experiments or laboratory activities were carried out among them. In using this method, students understood one-dimensional kinematic graph as a material of Regular Straight Motion and Regular Changeable Motion with the formula $s = v. t$. Most students used books as a learning media, while some of them used online media such as YouTube and material blogs.

During the process of intervention, students were directly involved in the process of questioning and answering. Active students also provided a long enough response, especially with semi-active and passive students. It happened because every student needed different time to think. Albergaria-Almeida (2010)a suggested that important changes in practice are found after intervention, especially in matters of waiting time, number and type of questions, for teachers and students. Socrates' questioning requires students to think critically, gather information as much as possible by collaborating answered questions with the right concepts. In line with these findings, Questions as learning tools to assess students' knowledge, improve their understanding, and stimulate their critical thinking (Tofade et al., 2013). One of the main goals of education is to develop critical and creative thinking, which can be achieved by in-depth learning called question and answer (Albergaria-Almeida, 2010b). Collaborative questions are used to generate convergence among learning tasks, class interactions, and learning outcomes (Ng'ambi, 2006a). Collaboration with students who are prospective teachers increases their pedagogical knowledge (Milner-Bolotin et al., 2016). From that, the collaborative Socratic questioning that was carried out had a significant impact on the mastery of concepts of students.

The significance of learning was accompanied by web-based formative assessment that provided effective feedback to students. E-learning used as a medium provided the opportunity for students to discuss, get information, and try their skills with quizzes. Online discussions provided opportunities for students to interact, exchange information, and improve the knowledge they already have. Technology creates a different social regime when it is used by several people in asking questions, resulting in continuous interactions where members comment on something posted by one of them (Rughiniş et al., 2014). Student-directed activities can facilitate the development of abilities accompanied by feedback from other students and themselves (Valdez et al., 2014). Formative assessment assisted by computers is a valid instrument for diagnosing students' understanding of concepts in a well-structured declarative knowledge (Maier et al., 2016). Interactive online formative assessment can improve students' overall learning experience (Bijol et al., 2015).

Collaborative Socratic questioning is a learning method that is useful and has more strength to implement a web-based formative assessment (Ng'ambi, 2006a).

Learning results in an increase in mastering concepts that are not evenly distributed because each student has different abilities. Special handling is needed on topics that are considered difficult to master by students (the area under the curve in this study). In line with these suggestions, Area below the graph can be compared with other concepts such as vectors and mathematics in learning (Lichtenberger et al., 2017). Some students cannot access e-learning that has been provided due to poor internet connection. A good internet connection and the timing of access must be considered so that all students can learn well.

Conclusions and recommendations

Students' understanding of concepts on one-dimensional kinematic graphs increased after learning with collaborative Socratic questioning accompanied by web-based formative assessment. This learning is significant with an increase in mastering the concept in the medium category. Students are honed by their concept of one-dimensional motion when given Socrates questions and they can exchange information continuously on learning systems in e-learning.

The area under the graph requires more attention to one-dimensional kinematic material with more intensive and in-depth questions and answers and multiplying practice questions that students can learn in e-learning. Effective feedback does not always arise from other students, so teachers must accompany and play an active role during online discussions so that questions and answers will be in line with the problems that arise. In addition, giving a ranking in each quiz provides more motivation for students. This certainly requires further research to improve students' ability, especially in the field of physics.

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