International Journal of Instruction *October 2019 ● Vol.12, No.4*
e-ISSN: 1308-1470 ● www.e-iji.net *p-ISSN: 1694-609X*
pp. 353-364

Received: 07/01/2019
Revision: 07/06/2019
Accepted: 13/06/2019
OnlineFirst:22/08/2019

Analysis of Students' Understanding of Motion in Straight Line Concepts: Modeling Instruction with Formative E-Assessment

Sentot Kusairi
Universitas Negeri Malang, Indonesia, *sentot.kusairi.fmipa@um.ac.id*

Lelitha Noviandari
Universitas Negeri Malang, Indonesia, *lelitanovi@gmail.com*

Parno
Universitas Negeri Malang, Indonesia, *parno.fmipa@um.ac.id*

Hastiningtyas Yuli Pratiwi
Universitas Kanjuruhan Malang, Indonesia, *hesti@unikama.ac.id*

This study aims to analyze the students' understanding of motion in straight line concepts and their difficulties after the learning process. The research method is a mixed method with an embedded experimental design. The research was conducted in one of the public senior high schools in Malang City Indonesia with 34 students consisting of 20 women and 14 men. The research instrument was used reasoned multiple-choice questions with a reliability of 0.814. The results showed that integrated Formative E-Assessment in modeling instruction learning significantly improved students' understanding of concepts with N-gain = 0.41 and d effect size = 1.902. Found some difficulties experienced by students after learning takes place, among others, in understanding the graph of the position and speed of time. The combination of modeling instruction with e-formative assessment can be an alternative to improve students' understanding of motion in straight line.

Keywords: understanding of physics concepts, modeling instruction, formative e-assessment, straight line motion, e-assessment, instruction

INTRODUCTION

Motion in straight line is one of the essential concepts in school physics lessons. Motion in straight line is the basis for studying the next physical material (Serway & Jewett, 2004). adequate graphs of position, speed, and acceleration of time (Bollen et al., 2016;

Citation: Kusairi, S., Novandari, L., Parno, & Pratiwi, H. Y. (2019). Analysis of Students' Understanding of Motion in Straight Line Concepts: Modeling Instruction with Formative E-Assessment. *International Journal of Instruction*, 12(4), 353-364. https://doi.org/10.29333/iji.2019.12423a

Klein et al., 2017; Zavala et al., 2017). If students succeed in mastering this material well, students will more easily learn more complex physics concepts.

Research shows that students have difficulty learning the concept of motion in straight line. Pujianto (2013) found that only 21.67% of class X students understood the concept of motion in straight line well, the rest experienced misconceptions. Students also have difficulties in distinguishing the magnitude of position, speed, and acceleration (Sutopo & Waldrip, 2013; Hestenes et al., 1992; Obidat & Malkawi, 2009; Lichtenberger, 2016). In addition, students also have difficulty interpreting the graph of the relationship between position, speed, and acceleration of time in motion in straight line (Bollen et al., 2016; Erceg & Aviani, 2012; Klein et al., 2017; Reddy, 2016; Smith 2013; Zavala et al., 2017).

It takes effort to overcome the difficulties of students' understanding the concept of motion in straight line. Sutopo and Waldrip (2013) in their research applied a representative approach to conceptual reasoning and understanding. Yusro and Sasono (2016) used a guided inquiry-based illustrative module to improve student learning outcomes in motion in straight line concept. In addition, many studies have applied the Test of Understanding Graphs in Kinematics (TUG-K) to identify students' difficulties in interpreting graphs of the relationship between magnitudes on motion in straight line (Maries & Singh, 2013; Planinic et al., 2013; Zavala et al., 2017). However, a constructivist learning model is needed that involves students actively and helps students overcome difficulties in the concept of motion in a straight line.

One learning model that is predicted to be effective in shaping the cognitive structure of students is Modeling Instruction (Hestenes, 1997; Jackson et al., 2008; Sujarwanto et al., 2014; Jumadin et al., 2017; Wells et al., 1995). Modeling instruction gives space to students in constructing scientific knowledge and reasoning through investigative and modeling activities (Brewe et al., 2009; Jackson et al., 2008). Investigation and modeling can help students master good concepts, develop the ability to think and solve problems (Ektina et al., 2013). Modeling instruction is carried out through two stages, namely the development model and deployment model (Jackson et al., 2008). In outline, students build a model at the stage of the development model through practical activities and further discussion apply the models obtained to solve problems in the deployment model (Sujarwanto et al., 2014).

In addition to the learning model, the factor that can influence students' understanding of concepts is formative assessment. Formative e-assessment can monitor the progress of learning, monitor learning outcomes, and detect continuous improvement of student learning outcomes (Bennett, 2011; Permendikbud No. 104, 2014), In other words formative e-assessment can provide continuous feedback. Formative feedback is seen as the key to advancing learning (Kleij et al., 2015). By giving feedback, students can find out the results they get, help students to increase student motivation and trust, modify, make decisions, and improve their learning processes and with students have more opportunities to achieve the competencies assessed (Pla-Campas et al., 2016). In addition, formative e-assessment is an innovative strategy in learning that involves several forms of performance measurement that reflect student learning, achievement, motivation, self-regulation and metacognition, skills, and attitudes that are compatible with learning material (Raymond et al., 2013; Villarroel et al., 2017; Pasaribu, 2016).

This study aims to analyze the students' understanding of motion in straight line concepts and their difficulties after the learning process and find out the difficulties experienced by students after carrying out integrated Formative E-Assessment in Modeling Instruction learning.

METHOD

Research Design

The model of this study is a mixed method study with embedded experimental design as a Figure 1 (Creswell, 2014; Edmonds and Kennedy, 2017).

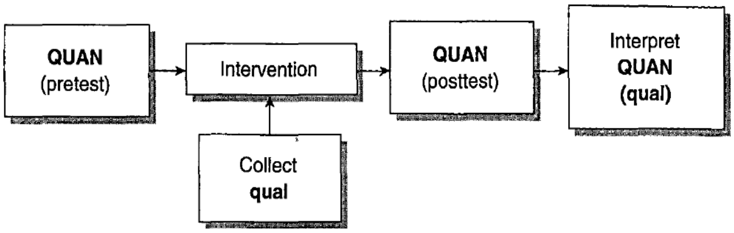


Figure 1
Mixed Method: Embedded Design (Edmonds and Kennedy, 2017)

The study began with the giving of a pretest to find out the students' understanding of initial concepts. Learning is done using Formative-Authentic E-Assessment integrated in Modeling Instruction. The learning activity is divided into two subtopics namely regular motion in straight line (RMSL) and Regular Changed motion in straight line (RCMSL). Learning in each subtopic is carried out through two stages, namely the development model and the deployment model. In addition to classroom learning, to support the implementation of Formative Authentic E-Assessment online learning is done using e-learning web. Broadly speaking the learning of straight-line motion material with integrated Formative E-Assessment Modeling Instruction is presented through a flow diagram in Figure 2. The study ended with the giving of posttest.

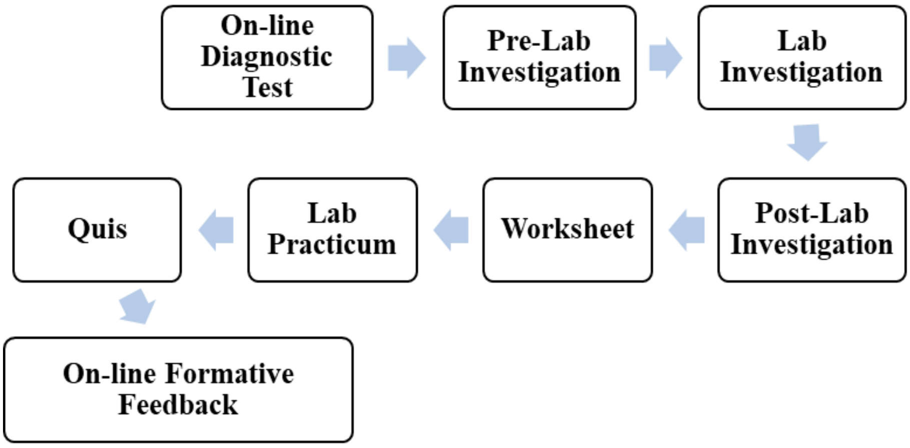


Figure 2
Flow Chart of the Integrated Formative E-Assessment in Modelling Instruction Learning

Respondents

This research was conducted in one of the State High Schools in Malang in the odd semester of the 2018/2019 academic year. The research subjects in this study were 34 students of senior high school SMA 6 Malang Indonesia consisting of 20 women and 14 men. Determination of the subject of the study was conducted using a purposive sampling technique (Sugiyono, 2011**).** Purposive sample selection is intended to ensure that students in one class have the facility to assess formative e-assessment.

Instruments

The research instrument consisted of 18 items of reasoned multiple-choice tests with reliability of 0.814. Question items were developed from conceptual questions in physics textbooks (Serway & Jewett, 2004) and some that have been developed by previous researchers (Obidat & Malkawi, 2009; Zavala et al., 2017; Planinic et al., 2013; Smith, 2013; Hestenes et al., 1992) This item was used twice namely before learning the pretest and after learning (posttest). Indicators for each item can be seen in Table 1.

Table 1
Learning Indicators

Indicators	Item Numbers
Describe the graph of the position with time on RMSL and RCMSL	3, 6, 10
Describe the graph of speed with time on RMSL and RCMSL	13, 15
Determine the speed of the object based on the graph in RMSL and RCMSL	1, 5, 12
Determine the acceleration of objects in RMSL and RCMSL	4, 7, 19
Determine compatibility between two graphs in RMSL and RCMSL	11, 14
Describe the motion of objects based on a diagram	8, 20, 22
Analyze RCMSL on objects that move vertically	17, 21

Data Analysis

Quantitative data analysis techniques were carried out to determine how much the students' understanding of concepts improved by using normalized gain and how strong the students' understanding concepts was by using the Cohen's d-effect size. Qualitative descriptive data analysis techniques were used to explain students' difficulties in mastering concepts.

FINDINGS

The results of the study in the form of pre-test and post-test scores are briefly presented in Table 2.

Table 2
Descriptive Statistics of Concept Mastery

Descriptive Statistics	Pre-test	Post-test
N	34	34
Mean	30.56	60.13
Maximum	66.67	88.89
Minimum	5.56	27.78
Standard Deviation	15.06	16.04

The percentage of students' understanding of concepts as a whole in each subtopic in the straight-motion material can be seen from the percentage of students who are successful in answering the questions of mastery of the concepts correctly on each indicator. The following Table 3 presents the percentage of students' understanding of concepts based on learning indicators.

Table 3
Percent Correct of Students' Response in Every Learning Indicators

Learning Indicator	Percent Correct (%)	
	Pre-test	Post-test
Describe the graph of the position with time on RMSL and RCMSL	16.67	53.92
Describe the graph of speed with time on RMSL and RCMSL	30.88	63.24
Determine the speed of the object based on the graph in RMSL and RCMSL	54.90	67.65
Determine the acceleration of objects in RMSL and RCMSL	42.16	58.82
Determine compatibility between two graphs in RMSL and RCMSL	23.53	80.88
Describe the motion of objects based on a diagram	31.37	44.12
Analyze RCMSL on objects that move vertically	2.94	60.29

Based on the Table 3, it can be seen that the mastery of students' concepts has increased from the pretest score to the posttest. To find out how much students mastered the concept from pretest to posttest, Normalize Gain was calculated. The average normalized gain is in Table 4.

Table 4
Normalized Gain

	Normalized Gain	Category
Mean	0.4101	Medium Low

All students who were the subjects of the study experienced an increase in understanding of the concept with a normalized average gain of 0.4101 which was categorized as moderate (Hake, 1999) or lower medium (Sutopo & Waldrip, 2014). The increase in mastery of the concept is the impact of giving treatment in this study, namely learning with the Formative-Authentic E-Assessment integrated Modeling Instruction model. To find out how strong the impact given by learning integrated Formative Authentic E-Assessment Modeling Instruction models to increase mastery of students' concepts, a *d*-effect size calculation was performed.

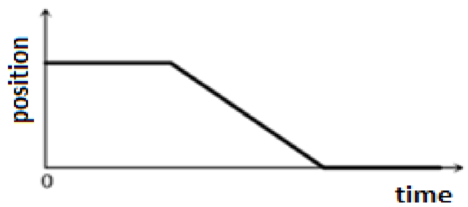
Table 5
d-Effect Size

d-Effect Size	1,902
Category	Bigger than standard

A value of d effect size of 1.902 was obtained, then the impact given by learning integrated Formative Authentic E-Assessment Modelling Instruction model to increase student mastery of concepts is categorized as greater than the standard (Morgan et al., 2004).

Although this study has an impact of increasing mastery of students' concepts, there are still some students who have difficulty in understanding the concept of straight-line motion. Difficulties experienced by students can be known through the reasons students answers in the pre-test and post-test. Difficulties can be seen from the results of working on the concept mastery test in item number 3. In this question students are asked to describe the motion of objects accompanied by their direction based on the graph of the position of the time presented in the question. The following are presented in terms of understanding of concept item number 3.

Position (s) - time (t) graph of an object motion is shown below.



The correct statement is ...

a. The object rolls along a flat surface. Then it rolls forward down a hill, and then finally stops. **(*Pre* : 73,53 %, *Post* : 58,82 %)**

b. The object doesn't move at first. Then it rolls forward down a hill and finally stops. **(*Pre* : 0 %, *Post* : 2,94 %)**

c. The object is moving at a constant velocity. Then it slows down and stops. **(*Pre* : 5,88 %, *Post* : 8,82 %)**

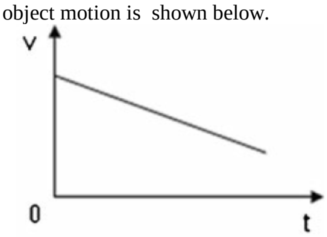
d.* The object doesn't move at first. Then it moves backwards and then finally stops. **(*Pre* : 0%, *Post* : 20,59%)**

e. The object moves along a flat area, moves backwards down a hill, and then it keeps moving. **(*Pre* : 14,71%, *Post* : 8,82%)**

Most students answered option A both at the pre-test and post-test. Of the students who answered option D only 7 students answered at the post-test. Even in the pre-test there were no students who answered D. If viewed from the reason of the answer, students answered option A because students assumed that the curve in the graph describes the speed of the object, even though the graph is written on the vertical axis and describes the position of the object not the speed of the object. This is probably because students still do not understand the graph of the relationship between position, speed, and acceleration of time in straight line motion and students do not understand the direction of motion of objects if depicted on the graph. Thus, students also experience difficulties in interpreting the graph of the motion of an object.

The next difficulty can be seen from the results of the concept understanding test in question number 13. In this question, students are asked to determine the acceleration of the motion of the object based on the graph of speed against time presented in the question. Below, there are items about understanding of concept number 13 and responses given by students.

Velocity (v)-time (t) graph of an object motion is shown below.



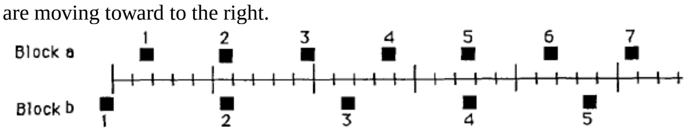
The statement best describes this motion is …

a.* The object is moving with a constant non-zero acceleration **(*Pre* : 5,88%, *Post* : 41,18%)**
b. The object is moving with zero acceleration **(*Pre* : 2,94%, *Post* : 0 %)**
c. The object is moving with a uniformly increasing acceleration **(*Pre* : 2,94 %, *Post* : 0%)**
d. The object is moving with a uniformly decreasing acceleration **(*Pre* : 82,45 %, *Post* : 58,82%)**

Most students answered option D both in the pre-test and post-test. At the pre-test as many as 28 students answered option D while at the post-test there were 20 students. Whereas students who answered option A (correct answer) were only 14 students at the post-test, even at the pre-test only 2 students answered A. If viewed from the reason of the answer, students answered option D because students assumed that if the object experienced a change in speed in this case decrease in speed, then the object also experiences a change in acceleration. This is probably due to students still not fully mastering the concept of acceleration, so they cannot distinguish between speed and acceleration. So, if speed changes, it should not necessarily accelerate changes.

The next difficulty can be seen from the students' responses to item number 8. On the question students are asked to determine the acceleration based on the motion diagram of the object. The following items are presented in terms of mastering concept related item number 8 and student responses.

The positions of two blocks at successive intervals each of 0.3 seconds, are shown in the figure below. The blocks are moving toward to the right.



The accelerations of the two blocks are …

a. The acceleration of block "**a**" is larger than the acceleration of block "**b**". **(*Pre* : 0 %, *Post* : 11,76 %)**

b. The acceleration of block "**a**" is smaller than the acceleration of block "**b**". **(*Pre* : 79,41 %, *Post* : 58,82%)**

c. The acceleration of block "**a**" equals the acceleration of block "**b**". Both accelerations are larger than zero. **(*Pre* : 0 %, *Post* : 0 %)**

d.* The acceleration of block "**a**" equals the acceleration of block "**b**". Both accelerations are zero. **(*Pre* : 17,65 %, *Post* : 29,41 %)**

It can be seen that most students answer option B both at pre-test and post-test. At the pre-test as many as 27 students answered option B while at the post-test there were 20 students. Students who answered option D were only 10 students at the post-test. When viewed from the reason of the answer, students answer option B because students assume that a beam moves slower than beam B because of shorter spacing, so then they assume that the speed of an object is proportional to its acceleration, so they conclude that the acceleration of a beam is smaller than acceleration of the beam b. This is probably due to students not yet understanding in depth about the concept of acceleration which is actually a change of pace and students have difficulty interpreting the motion diagram of objects.

DISCUSSION

The results showed an increase in students' understanding of straight-motion concepts with an average N-gain value of 0.4101 which was categorized as moderate (Hake, 1999) or lower medium (Sutopo & Waldrip, 2014). This shows that students experience a change in understanding of the concept of straight motion. This is supported by the calculation of the d effect size, which obtained a value of 1.902 which is categorized as greater than the standard (Morgan et al, 2004) or strong (Cohen, 2011). Then it can be interpreted that the Formative Authentic E-Assessment integrated Modeling Instruction learning has a strong impact on improving students' understanding of concepts**.**

Modeling Instruction learning is basically learning through investigation and modeling. The investigation activity helps students in developing the concept of straight line motion. This is consistent with the results of research conducted by Jackson et al (2008) that understanding of the concept of students learning with Modeling Instruction has doubled compared to students who study with conventional learning. In addition, Brewe et al (2009) found that students' success in Modeling Instruction learning was 6.73 times greater than lecture learning. Modeling Instruction helps students have the ability to master good concepts, develop the ability to think and solve problems (Helmi, 2011) and help students construct a better, structured and systematic understanding of physics (Wells et al., 1995).

In addition to the learning model, Formative E-Assessment also helps students improve understanding of concepts. Formative E-Assessment implementation by giving multiple-choice recitation helps students in learning and identifying concepts that have not been mastered so as to help students improve understanding of concepts. This is in accordance with the results of the study of Sutopo et al. (2017) that computer-based recitation programs significantly improved students' understanding of concepts. In addition, with the provision of authentic assignments students can apply what they have learned into other contexts (Dennis et al., 2013). Wijayanti (2014) found that the development of assessment can improve understanding of concepts and ability to think critically. Through the Formative E-Assessment students can also get feedback effectively and on time. By giving feedback, students can find out their learning outcomes, help students increase their motivation and self-confidence, modify, make decisions, and improve their learning processes and have more opportunities to achieve competencies (Pla-Campas et al., 2016).

Although it can help students understand the concept, there are still some students who have difficulty understanding straight line motion concepts. Students experience many difficulties in terms of 1) distinguishing between speed and acceleration, 2) interpreting graphs and motion diagrams of objects. The difficulty was also revealed by some previous researchers that students had difficulty distinguishing between the magnitude of position, speed, and acceleration (Sutopo & Waldrip, 2013; Hestenes et al., 1992; Rosenblaatt & Hecker, 2011; Obidates & Malkawi, 2009; Lichtenberger, 2016) and students also have difficulty in interpreting the graph of the relationship between position, speed, and acceleration of time in straight line motion (Bollen et al., 2016; Erceg & Aviani, 2012; Klein et al., 2017; Reddy, 2016; Smith 2013; Zavala et al., 2017).

Based on the difficulties described, it is recommended that students are more often trained to interpret real motion in the form of graphs and diagrams and vice versa and students are more often stressed about the concept of the difference between the magnitude of position, speed and acceleration in the motion of objects. In addition, students need to be given conceptual practice questions and balanced calculation questions. For further research this research can be carried out using quasi experiments with the aim of seeing the effectiveness of learning.

CONCLUSION

Mastery of the concept of students who learn with Formative E-Assessment in Modeling Instruction has increased which is included in the category of lower or medium (N-gain = 0.401) with increasing strength in the high category (d effect size = 1.902). The difficulties experienced by students in understanding the concept of straight-line motion are 1) distinguishing between speed and acceleration, 2) interpreting graphs and motion diagrams of objects.

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