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Hypothetical Learning Trajectory for Uniform Motion and Gradient Using the STEM Approach

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Abstract: Learning in the fields of science, technology, engineering, and mathematics (STEM) has developed into a meta-discipline. Learning in all four fields is focused on the emergence of innovative solutions to a complex contextual problem facing the world today. The purpose of this study was to describe the design of teaching and learning about uniform motion in science and gradient of a line on Mathematics using the STEM approach. The type of research used in this study was the design of the Gravemeijer and Cobb models which consist of three phases. The exposure presented in this paper was only limited to the first phase of design research. The research subjects in this study were class VIII of SMPN 2 Yogyakarta. The instrument used in this study is the hypothetical learning trajectory. In the design made by researchers, researchers will experiment with dropping mahogany trees from a certain height. From this experiment, researchers will build understanding and meaning of the concepts of regular straight motion and straight-line gradients.

Keywords: STEM approach, uniform motion, gradient

Introduction

Students in SMP Negeri 2 Yogyakarta have an average score above the average of students in general in the city of Yogyakarta, but their communication skills are not in accordance with the academic abilities they have. This can be seen from the way they answer the questions in science and mathematics, students tend to only write the final answer, not writing the steps to solve the problem. This is because students' ability to describe what they think in writing is not good. Likewise, with their verbal communication skills. When students present the results of the experiment, students only read what they wrote in the notes, they have not explained how process took place and how their process obtained the experimental results.

When students learn the material of linear equations, students have difficulty in interpreting gradients from a straight line, and represent mathematically two parallel lines, perpendicular or coincident in the equation of straight lines. For example, students cannot explain what means a line has a gradient of 1/3 and which of the two lines is more upright if the gradients of the two lines are 1/2 and 1/4. Students are also still difficult to understand why if two parallel lines are known, then the gradients of the two lines are the same or if the two lines are perpendicular to each other, then the product of the multiplication of the two lines is -1. When students solve questions in the material of linear equations, students use more formulas that have been derived by the teacher than the meaning of straight-line gradients and the relationship between gradients of 2 straight lines.

In science learning at Yogyakarta State Junior High School 2 especially in linear motion material students experience difficulties in making and reading charts. So that at the time of presentation students cannot explain in detail about the results of the experiments they did. For example, students find it difficult to explain the results of the experiments they did in relation to regular straight motion. They experimented using a ticker timer and dropped mahogany flowers.

The problem that explained above encourages researchers to try to make hypothetical learning trajectory design that can teach material linear equations in Mathematics and regular linear motion in science subjects in integration. The results in this paper is still limited by researchers in the explanation of how the hypothetical learning trajectory is to teach material linear equations in Mathematics and regular linear motion in science subjects using the STEM approach and paying attention to the communication process of students verbally and in writing.

STEM is an integrated learning between science, technology, engineering, and mathematics to develop students' creativity through the process of solving problems in daily life (Winarni, Zubaidah, & Koes, 2016). The aim of STEM learning for students is to deliver students to meet 21st century capabilities, among others, learning and innovating skills which include: thinking critically and being able to solve problems, creative and innovative, and able to communicate and collaborate, skilled in using media, technology, information and communication (ICT) (Winarni et al., 2016).

William F. Glueck (in Winarni et al., 2016) said that communication can be divided into two forms, namely as follows: (a) interpersonal communications, and (b) organization communications. According to William F. Glueck (in Winarni et al., 2016) interpersonal communications is a process of information exchange and transfer of understanding between two or more people in a small group of people, while an organization communication is a process where the speaker systematically provides information and move understanding to many people in the organization and to individuals and institutions outside of the relationship. Widjaya said that the notion of communication is a contact relationship between and between humans both individuals and groups (As'ari, Tohir, Valentino, Imron, & Taufiq, 2017a).

According to Gravemeijer and Cobb (in Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006) there are three phases in design research, namely:

1. The first phase, namely preparation of design trials According to Gravemeijer and Cobb (in Van den Akker et al., 2006), preparation for design trials begins with setting goals to be achieved by students after they learn mathematics which are referred to as design endpoints. After completing setting goals to be achieved by students, the researcher must then determine the starting points of learning, which are referred to as the starting points of the design. After the objectives to be achieved by students and the starting points of learning are formulated, then the next task of the researcher is to formulate the guesswork of local learning theory (a conjecturer local instruction theory) of the design to be tested.
2. The second phase, namely the design trial. According to Gravemeijer and Cobb (in Van den Akker et al., 2006), the purpose of the design trial is to test and increase the suspicion of local learning theory (a conjecture local instruction theory) that has been developed in the first phase and develop understanding of how the design works. According to Gravemeijer and Cobb (in Akker et al., 2006), the key to the process of testing, improvement, and understanding is an integrated cyclic process of the design and analysis process.
3. The third phase, namely retrospective analysis According to Gravemeijer and Cobb (in Van den Akker et al., 2006), the purpose of the retrospective analysis depends on the objectives of the theoretical research development carried out. Furthermore, it was stated that one of the main objectives of a retrospective analysis was to develop a local learning theory. Despite the differences in objectives in theory the development of research is reflected in differences in retrospective analysis, but the form of analysis needs to include an iterative process that analyzes the incoming data set.

Research Method

In this study we use design research whose model of Gravemeijer and Cobb (in Van den Akker et al., 2006) which has the following characteristics: (1) Interventionist, which mean design research has the purpose of designing an intervention in the real world; (2) Iterative, which mean that in the design research process there is a cycle (a) design, (b) evaluation, and (3) revision; (3) Process oriented, which mean that research is focused on understanding the process and the impacts that occur in the intervention carried out by researchers and the development of interventions; (4) Utility oriented, which mean the usefulness of this research is measured by practicality for users; and (5) Theory oriented, which mean that the design is built based on theoretical prepositions then field testing is done to contribute to the theory.

The subjects of this study were class VIII students. The research instrument used in this study is a field note that is used to record all the processes of implementing learning in the classroom and communication skills both oral and written that are shown by students during the learning process, and

the tests used to see how the ability impacts students in regular straight-line material and straight-line equations and written communication skills of students. The research method used in this study is to make field notes and carry out tests. Field notes are made during the learning process and after the learning process is complete. The test is done at the end of the learning process. Data analysis was carried out following data analysis in qualitative research, namely (1) reducing data, (2) presenting data, (3) and making conclusions (Miles & Huberman, 1994).

Discussion

The results presented in this new paper are limited to the results achieved by researchers in phase one of design research. The aim of the learning process designed by researchers is (1) for mathematics subjects so that students (a) interpret the meaning of gradients in linear equations (mathematics), (b) identify whether a graph is a graph of a linear equation or not, and (c) determine the equation of a linear graph; for science subjects is that (a) students can explain the phenomenon of regular linear motion, (b) make and read graphs about linear motion, (3) conduct experiments with mahogany flowers and ticker timers, and (4) report in writing the results obtained from experiments with mahogany flowers and ticker timers; (3) for the communication aspect so that students can (a) make exposure, which is coherent and systematic, in writing about the results obtained from the experiment with mahogany flowers and ticker timers, and (2) present, coherently and systematically the results obtained from the results of experiments with mahogany flowers and ticker timers.

Before learning about straight line equations and regular straight motion, students have learned about (1) equations, (2) variables, constants, coefficients, and terms, (3) Cartesian coordinates, (4) distance and displacement, and (5) speed (As'ari et al., 2017a; As'ari, Tohir, Valentino, & Imron, 2017b; As'ari et al., 2017c; Widodo, Rachmadiarti, & Hidayati, 2017; Zubaidah, Mahanal, & Yuliati, 2017a; Zubaidah, Mahanal, & Yuliati, 2017b).

The activities carried out by teachers and students designed by researchers for the first meeting planned to last for 5 × 40 minutes are as follows:

1. The teacher greets students.
2. Students and teachers pray to begin the lesson.
3. The teacher checks the attendance of students.
4. The teacher conveys the learning objectives to students.
5. Students observe the marbles phenomenon which is rolled on a board that is not tilted and tilted.
6. Teachers and students discuss the observed phenomenon. To start discussion, the teacher can give the following question, what is the difference in the condition between the marbles rolled on the board that are not tilted and tilted? What is the speed of the marbles that are rolled on the board that is not tilted with the tilted one? Can you explain why the marbles that are rolled on the tilted board have increased speed, while the marbles that are rolled on the board that are not tilted do not experience an increase in speed.
7. The teacher organizes students in several groups (each group consists of 8 students).
8. Teachers share student worksheets that need to be done by students. The following is a student worksheet that is shared with students:

STUDENTS' WORKSHEET

1) OBJECTIVE: students analyze the phenomenon of mahogany fall with the tracker program.

2) TOOLS AND MATERIALS: cellphones for recording videos, laptops equipped with tracker programs, and mahogany flowers

3) EXPERIMENT STEPS:

a) Drop a mahogany flower from a certain height.
b) Video the process of falling mahogany flowers.
c) Perform the first and second steps three times from different heights.
d) Analysis of videos with the tracker program, for that to do the following steps:

(1) install the tracker program on the laptop that will be used.
(2) open the tracker program.
(3) open file choose the video that will be analyzed.
(4) right click on mouse – filter – new – rotate (pilih yang tepat) – close.
(5) see the video and specify the start and end times of the moving object by clicking clip settings – start frame.....- end frame..... ok.
(6) create a calibration line with the following steps: click show- new – calibration stick. On the keyboard press shift and click at the beginning of the moving object - press shift and click on the end of the moving object.
(7) change the length.
(8) make coordinate line .. pull it put in the middle of the object is hidden.
(9) analyze the video by clicking create – point mass.
(10) press shift and control together and click on the ball - dialog box appears - shift and control is released - click search - close.
(11) click 2x on the digraphic table section, then a new table will appear - click measure - coordinates checked..lope checked.area checked.
(12) click analyze- statistics checked – curve fits checked.
(13) observed the results,
(14) make conclusions about the phenomenon of mahogany. Explain the phenomenon from a scientific perspective.

9. Each group made a poster explaining the trial process carried out and the results obtained from the experiments conducted by them.
10. Give the opportunity to two to three groups to explain the trial process they did and the results obtained from the experiments conducted by them.
11. Students are invited to conduct class discussions about the phenomenon of falling mahogany flowers. The teacher directs the discussion so that students can (1) explain that the phenomenon of falling mahogany is a phenomenon of regular linear motion, (2) explaining why the phenomenon is a phenomenon of linear straight motion, and (3) defining regular linear motion.
12. Take one of the charts produced by one of the groups obtained from the experiment of dropping the mahogany flower and display the graphic so that each student can see the graph clearly.
13. Ask students to make discussion groups consisting of 2-3 students.
14. Ask students to discuss the following questions: (1) whether the graph is a straight line, (2) what the slope of the line from the graph is, (3) the slope of the line expresses what phenomenon in trying to drop the mahogany flower, and (4) determine the equation the straight line.
15. Each group was asked to write the results of their discussion on poster paper.
16. Ask one to three groups to explain the results of their discussion.
17. Invite students to have class discussions. Direct the discussion so that students can (1) explain that the graph of a straight line equation is a straight line, (2) interpret the meaning of the slope of the line using the phenomenon of mahogany flower fallout, (3) identify whether a graph is a graph of straight line equations or not, (4) explain the steps to find the equation of a straight line, and (5) find the equation of a straight line.

The activities carried out by teachers and students designed by researchers for the second meeting planned to last for 5 × 40 minutes are as follows:

1. The teacher greets students.
2. Students and teachers pray to begin the lesson.
3. The teacher checks the attendance of students.
4. The teacher reviews the previous meeting learning again.
5. The teacher tells the students about the learning objectives.

6. The teacher provides an overview of the activities and assessments that will be carried out at this meeting.
7. Students in groups (each group consists of 8 students) and groups is the same with the first meeting
8. Students look for objects that move straightly irregularly outside the class and record them.
9. Students analyze the results of the video with the tracker program.
10. Each group made a poster explaining the trial process carried out and the results obtained from the experiments conducted by them.
11. Give the opportunity to two to three groups to explain the trial process they did and the results obtained from the experiments conducted by them.
12. Students are invited to conduct class discussions about the phenomena observed by students. The teacher directs the discussion so that students can (1) explain that the phenomenon is a phenomenon of regular linear motion, (2) explain why the phenomenon is a phenomenon of regular linear motion, and (3) define regular linear motion.
13. Take one of the charts produced by one group obtained from observing the phenomenon of regular straight motion and display the graph so that each student can see the graph clearly.
14. Ask students to make discussion groups consisting of 2-3 students.
15. Ask students to discuss the following questions: (1) whether the graph is a straight line, (2) what the slope of the line from the graph is, (3) the slope of the line expresses what phenomenon in trying to drop the mahogany flower, and (4) determine the equation the straight line.
16. Each group was asked to write the results of their discussion on poster paper.
17. Ask one to three groups to explain the results of their discussion.
18. Invite students to have class discussions. Direct the discussion so that students can (1) explain that the graph of a straight line equation is a straight line, (2) interpret the meaning of the slope of the line using the phenomenon of mahogany flower fallout, (3) identify whether a graph is a graph of straight line equations or not, (4) explain the steps to find the equation of a straight line, and (5) find the equation of a straight line.

Conclusion

There are several conclusions that can be concluded from the discussion above, that are:

1. The phenomenon of the fall of mahogany can be one of the phenomena that can be observed by students to learn regular straight motion.
2. The experimental results obtained from observing the fall of mahogany can also be used to be a phenomenon for students learning about (1) explaining that the graph of a straight line equation is a straight line, (2) interpreting the meaning of the slope of the line using the phenomenon of mahogany fall flowers, (3) identify whether a graph is a graph of a straight line equation or not, (4) explain the steps to find the equation of a straight line, and (5) look for the equation of a straight line.
3. The results presented in this paper are only limited to the hypothetical learning trajectory, so researchers still need to conduct field tests on this hypothetical learning trajectory.

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