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THE INFLUENCE OF THE 5E LEARNING CYCLE STRATEGY WITH A LINK MAP ON STUDENTS' MASTERY OF PHYSICS CONCEPTS AND SCIENCE PROCESS SKILLS

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ABSTRACT

Link maps help students correlate interconcepts in order to facilitate students mastery of the concept learned. The researcher accompanied the link map in learning to find out its effect on concept mastery and students science process skills. This study used a quasi-experimental research design by providing a posttest only for the control group. The sample consisted of two classes, divided into an experimental class and a control class. The experimental class was taught using the 5E learning cycle strategy accompanied by a link map, and the control class was taught using the 5E learning cycle strategy only. The results of the analysis showed that there were differences among students who studied using the learning cycle with link maps and students who studied using the 5E learning cycle only. The further test result indicated that students who learned using the 5E learning cycle with a link map had better concept mastery of physics and science process skills than those who studied using the 5E learning cycle alone.

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INTRODUCTION

Physics learning consists of three components, i.e. products, processes, and attitudes. Products and processes in learning can be achieved if students have science process skills and mastery of concepts. Science process skills are needed in the learning process to structure knowledge (Karsli & Şahin, 2009). Furthermore, science process skills are useful for acquiring, developing, and applying scientific concepts, principles, laws, and theories (Toharudin, Hendrawati & Rustaman, 2011), which makes it easier for students to solve cognitive problems (Akinbobola & Afolabi, 2010). Mastery of concepts also makes it easier for students to define concepts with words and their critical attributes (Arends, 2012). In addition, mastery of concepts helps develop students' knowledge so that it becomes the basis for continuing to the next level (Presiden Republik Indonesia, 2005).

Expectations for learning physics are contrary to existing reality. The problem found in previous studies is that teachers still dominate learning (teacher-centered) (Dewantari, Ashadi & Sugiharto, 2013). In addition, based on the results of teacher and student interviews at SMAN 1 Tuban and SMAN 2 Tuban, it was found that students are used to learning physics concepts using rote memorization techniques. Memorizing is done by students by listening to information from the teacher and other relevant sources accompanied by noting the formulas written by the teacher. Memorization techniques and teacher-centered learning make students activeless in the learning process (Kulsum & Hindarto, 2011). This resulted in most students not understanding the concepts that had been learned. Meanwhile, the problems in previous research also stated that the teacher conducted an experimental assessment only based on the results of the experimental evaluation (Sumarni, 2010). Evaluation of practicum results tends to only emphasize the product, ignoring the ongoing process. Science process skills and concept mastery should not be obtained by passively receiving information and memorizing it but must involve active participation from students through the construction of knowledge, skills, and thinking activities (Akinbobola & Afolabi, 2010).

One of the reasons for the application of learning that is not in accordance with the physics learning material is that students' science process skills and their level of understanding of physics ideas are not yet ideal. The selection of learning strategies should be adjusted to the material to be taught because material is the most important aspect of the learning process (Rusman, 2011). The selection of learning strategies needs to consider the material, whether in the form of facts, concepts, formulas, or theories.

The topic of elasticity and simple harmonic motion (SHM) is one of the topics consisting of concepts (Giancoli, 2005). Mastery of concepts and science process skills in concept material can be developed through constructivist learning (Suparno, 1997), which emphasizes student activity. Based on the results of the research, the activeness of students in forming knowledge about the concepts studied has an impact on students' mastery of concepts (Madu & Amaechi, 2012) and develops process skills and scientific attitudes (Yuliati, 2008).

Constructivist learning can be achieved through several strategies. One of the constructivist learning strategies that is widely used is the 5E learning cycle. Empirically, learning the 5E learning cycle can develop students' science process skills and mastery of concepts. The results of previous research stated that the 5E learning cycle had a positive effect on students' science process skills (Rahayu, Susanto & Yulianti, 2011; Sari, Mulyani & Utami, 2013; Polyiem, Nuangchalerm & Wongchantra, 2011). Meanwhile, the 5E learning cycle strategy has also proven to have a positive effect on mastery of concepts, in accordance with the results of previous studies (Madu & Amaechi, 2012; Madu, 2012; Kulsum & Hindarto, 2011; Ajaja & Eravwoke, 2012; Qarareh, 2012; Utari, Feranie, Aviyanti, Sari & Hasanah, 2013; Hirça, Çalik & Seven, 2011).

Contrary to the results of research on the advantages of learning the 5E learning cycle, other studies state that the 5E learning cycle also has weaknesses. Weaknesses of the 5E learning cycle strategy include taking a long time in the experimental phase (Sumarni, 2010), students still cannot understand the concepts found, so the teacher still has to explain again after exploration activities (Dewantari et al., 2013). In addition, the results of interviews with physics teachers at MA Bilingual Batu who applied the 5E learning cycle strategy revealed that students were weak at connecting concepts. The weakness of the 5E learning cycle strategy makes most teachers still hesitant to use it and choose to apply the lecture strategy.

The solution to overcome teacher doubts in applying the 5E learning cycle, especially in topics with complex concepts such as elasticity and simple harmonic motion, is a link map. In this case, the 5E learning cycle emphasizes the process of discovering concepts (Trowbridge & Bybee, 1986), while the link map emphasizes simplifying the links between concepts (Lindstrøm & Sharma, 2009). Link maps can make it easier for students to understand complex concepts by focusing on the interrelationships between concepts that have been studied and reducing irrelevant information.

Previous research that includes link maps in the learning process has been carried out by Ahda (2012). In this study a link map was developed to complement inquiry learning, the learning model was called Inquiry Link Map Learning (PILM). The research found that link map inquiry learning was able to develop students' physics thinking skills. In addition, the use of link maps as scaffolding in Think, Pair, and Share (TPS) learning has also been carried out by Amiroh (2014). The research found that the link map can help the learning achievement of students with low initial abilities.

Based on the results of research that has been done, the link map is proven to have complemented learning so that it can help students develop thinking skills and improve student achievement. Related to the products and processes that should be emphasized in learning physics, this study aims to determine the effect of the 5E learning cycle strategy accompanied by a link map on students' mastery of physics concepts and science process skills.

METHOD

This research is quasi-experimental, using two classes, one experimental class and one control class. The experimental class is the class that learns using the 5E learning cycle accompanied by a link map. The control class is the class that learns using the 5E learning cycle. This research focuses on elasticity and simple harmonic motion. This research design uses a posttest-only control group design.

The population in this study was class XI IPA at SMA Negeri 1 Tuban in the odd semester of the 2013/2014 academic year, which consisted of seven classes, namely class XI IPA 1, XI IPA 2, XI IPA 3, XI IPA 4, XI IPA 5, XI IPA 6, and XI IPA 7 with a total of 245 students, and the number of students from each class is 32 students. Samples were taken using the cluster sampling method. Class XI IPA 1 and XI IPA 3 were selected as the experimental class, while XI IPA 2 and XI IPA 5 as the control class.

Treatment instruments, including lesson plans and worksheets, were created and validated by two experts. Students' mastery of physics concepts is measured using a test instrument in 20 multiple-choice questions that were previously content-validated by two experts. Then, a trial is carried out to determine their validity and reliability. The student's mastery of the physics concepts test is obtained from the posttest results after completing the material on elasticity and simple harmonic motion (GHS). Question indicators include the ability to remember, understand, apply, analyze, evaluate, and create.

Science process skills are measured using a science process skills rubric whose data is collected during the experimental process and the experimental posttest. Two experts validated the science process skills rubric, and a trial was carried out to determine the validity and reliability of the instrument. The data analyzed is the average result of science process skill scores obtained during the experiment and experimental posttest. Indicators of scientific process skills studied include determining variables, formulating hypotheses, conducting experiments, interpreting data, compiling graphs, and concluding.

Data analysis was carried out using multivariate analysis of variance. Before testing the hypothesis, the data is subjected to prerequisite tests, namely, normality, variance homogeneity, variance-covariance homogeneity, and linearity tests.

RESULTS

The percentage of implementation of the learning process is presented in Table 1. The percentage of implementation in Table 1 shows that students and teachers increasingly understand the learning process. Based on the implementation of this learning, students' scientific work and learning achievements result from the applied learning process.

The learning process was carried out in 8 meetings. The elasticity topic was carried out in 2 meetings, while the simple harmonic motion topic was carried out in 4 meetings. After the teaching on elasticity and simple harmonic motion topic is completed, students are given a concept mastery test and an experimental test.

The percentage of student activities in experimental and control classes at the beginning of learning is still in the low category. The percentage of student activities only reached 7 out of 10. The low percentage of learning implementation was because students were not enthusiastic about new learning methods and new teachers. In this phase, student activities tend to be passive. When the teacher asked, "What is meant by an elastic object?", the students answered with a textual sentence from the book, "An elastic object is an object that can return to its original shape after the force that changes the shape is removed". When the teacher asked again, "What is the example of an elastic object?", all the students answered simultaneously according to the book, "Rubber and Copper". The teacher continued asking, "Is the force exerted to change the shape of rubber and copper the same or not?". Students began to appear doubtful. Some students answered "Same", while others answered "No". At this point, students' initial knowledge regarding elastic objects is still at the stage of stating definitions and examples.

The teacher continues learning by demonstrating activities to build students' initial concepts regarding the topic. Students began to enthusiastically pay attention to the teacher's explanations and answer the teacher's questions with their analysis without the help of books. At the end of the engagement phase, when the teacher asks questions about the demonstration activity, students can propose conclusions from what they observed. The teacher accommodates all students' answers without justifying or blaming them. Next, the teacher guides students to carry out exploration activities to prove the truth of the students' answers.

There were differences in treatment between the control and experimental classes in the exploration phase. In the control class, students were immediately asked to fill in the student worksheet (Lembar Kerja Siswa – LKS) the teacher gave. Meanwhile, in the experimental class, students were asked to complete the link map the teacher had prepared before filling in the worksheet. The link map for the spring force experiment that students completed in the pre-experiment phase is presented in Figure 1a.

All experimental and control class students carried out exploration activities in the exploration phase. The teacher distributes experimental worksheets for the experimental class and control worksheets for the control class. Before carrying out exploration activities, students must go through several stages, such as determining exploration variables, formulating hypotheses, conducting experiments, processing exploration data, compiling graphs, and making conclusions. Before the exploration, experimental class students were accustomed to completing the link map provided on the initial sheet of the LKS. Meanwhile, control class students were immediately asked to explore according to the LKS instructions after filling in all the question points on the LKS. Initially, the experimental class students still felt confused. However, after being guided by the teacher, the students began to understand what to fill in the link map, so that in the next exploration, the students were fluent in filling in the link map. Students in the experimental class were very fluent in determining variables. While in the control class, students still had difficulty identifying the independent and dependent variables. It causes students to be unable to be independent and often ask the teacher questions. Control class students' confusion regarding determining independent and dependent variables always occurs at every exploration phase.

At the stage of formulating a hypothesis in the exploration of spring force, experimental class students could formulate a hypothesis correctly. Most of the experimental class students wrote that force is directly proportional to the increase in length. This hypothesis is linear with the results of the exploration carried out. On the other hand, the formulation of hypotheses by control class students was not entirely in accordance with the results of the exploration carried out. Most control class students wrote that force is related to increasing in length. This hypothesis does not precisely and explicitly explain the relationship between force and length increase. In exploring spring vibrations and simple swings, control class students still had difficulty formulating hypotheses. Students tend to be passive and often ask the teacher questions.

Experimental and control class students can carry out experiments or explorations correctly. However, control class students asked more for guidance from the teacher because many still did not understand what to do. Experimental class students can assemble exploration tools correctly and explore according to the specified work steps. Assessments when conducting experiments are carried out on each student. Each student in the group takes turns taking data.

At the stage of explaining the data, all students in both the control class and the experimental class could completely fill in the data table the teacher gave. However, several control class students needed to be corrected in filling in the data table. Inaccuracy regarding units is an obstacle in explaining exploration data.

Table 1. Percentage of inquiry learning implementation for each topic.

Learning	Topic						Average	
	Elasticity		Spring Vibration		Simple Harmonic			
	Teacher (%)	Student (%)	Teacher (%)	Student (%)	Teacher (%)	Student (%)	Teacher (%)	Student (%)
5E Learning Cycle	87	76	95	81	96	91	92.7	82.6
5E Learning Cycle-Link Map	93	77	98	88	99	94	96.6	86.3

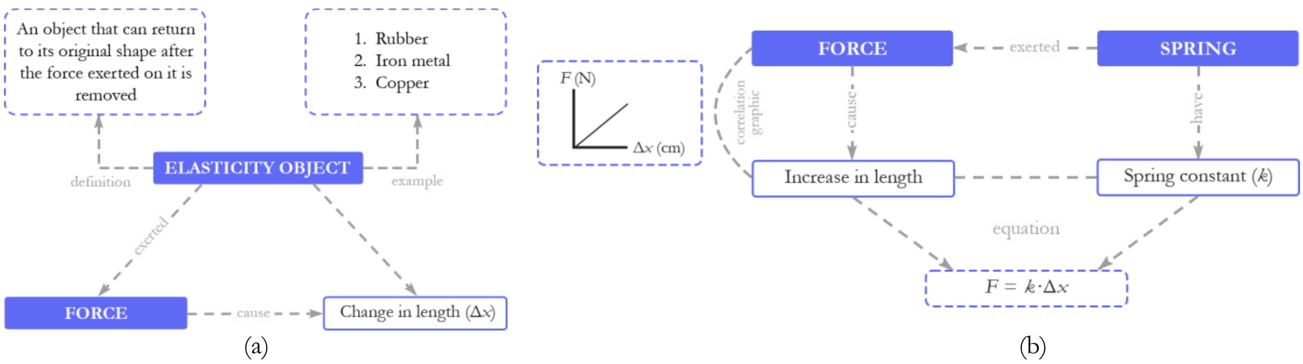

Figure 1. Link map for spring force experiment results of student work in the (a) pre-experiment phase and (b) exploration phase.

In the phase of preparing graphs of the relationship between force and length increase, in the experimental class, only 5 out of 8 groups could make graphs according to the teacher's expectations. In comparison, only 2 out of 8 groups succeeded in the control class. Most have been unable to make the correct scale proportions between variables x and y. During the exploration of spring vibrations and simple harmonic motion, experimental class students were able to create appropriate graphs. However, several control class students were still unable to arrange graphs correctly.

When making conclusions about exploring spring forces, students in the experimental and control classes primarily did not refer to predetermined hypotheses. Students only write down the raw results of data analysis, for example, "The spring will get longer when the force applied gets bigger". It is not appropriate. Students should be able to conclude that the increase in length is directly proportional to the force applied. So that if the force applied is large, the increase in length will also be greater. In exploring the vibrations of springs and simple harmonic motion, students have been able to make appropriate conclusions.

After the exploration phase, experimental class students return to complete the link map provided on the last page of the worksheet. When completing the link map, students looked enthusiastic about filling it in because they had to pay attention to the connecting words that had been determined. It was not done with control class students. In the exploration activities of the control class students only reach conclusions. The link map of the concept of spring force resulting from student work after the experimental phase is presented in Figure 1b.

Next, in the pre-explanation phase, students are asked to make connections between the link maps that were created during the pre-experimental phase and after the experimental phase. This activity aims to enable students to connect initial concepts and new concepts obtained. The link map for the concept of elasticity and simple harmonic motion is presented in Figure 2.

The second core phase in learning activities is the explanation phase. In this phase, control and experimental class students must present the concepts obtained during the exploration phase. Control class students presented the results of their exploration in the form of a data table of exploration results. Two students selected from each group for the presentation took turns coming to the front of the class to explain their exploration results to find the spring force equation. Experimental class students presented the results of their exploration to find the equation of spring force along with the relationship between concepts using a link map. Like the control class students, two students selected from each group in the experimental class explained the link map that had been created. Experimental class students seemed more enthusiastic about carrying out presentation activities. In this phase, the teacher allows students to create link maps as they wish, but the teacher's instructions still guide the concepts included.

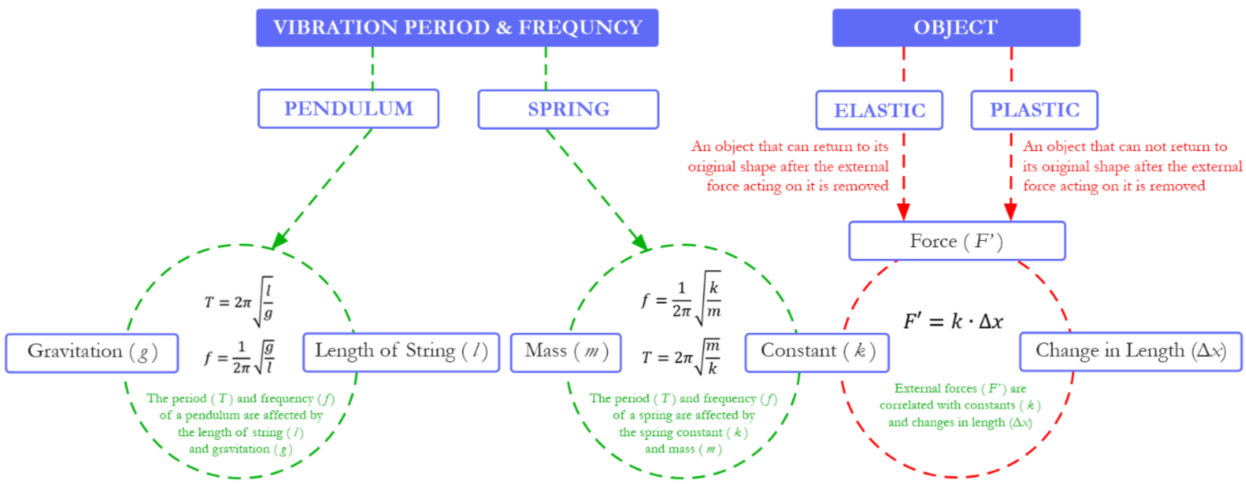

Figure 2. Link map about the concept of elasticity and simple harmonic motion.

In the third core phase, namely elaboration, students in both classes could apply the concepts obtained to new problems given by the teacher. Discussion activities to solve problems looked different between the two classes. Discussions in the experimental class can run according to the teacher's expectations. Each student in the group looks active and works together to solve problems with the help of the link map that has been created. The same thing was not seen in the control class. Discussion activities appear passive because only a few students try to solve the teacher's problems, while most students look indifferent.

The final phase of the learning process, namely evaluation, went well according to the learning plan. The evaluation phase for experimental class students can run well. All questions from the teacher can be answered fluently and precisely without looking at the book. Meanwhile, in the control class, students' activities during the evaluation phase looked passive. Only a few students can answer questions from the teacher. Most students still look at books and memorize equations. This condition becomes worse when it comes to the material of spring vibrations and simple harmonic motion, which contain many concepts and equations.

After all learning activities have been completed, the teacher conducts a posttest to determine students' mastery of concepts and science process skills through an exploration test. Concept mastery tests and exploration tests were carried out on different days. Concept mastery tests for both classes were carried out simultaneously, while exploration tests were carried out alternately. Overall, concept mastery tests and exploration tests ran well and on time.

DISCUSSION

Data on mastery of physics concepts was obtained by conducting a test at the end of the research. Data descriptions of students' physics learning achievement and scientific work are shown in Table 2, where PK is concept mastery and KPS is science process skills. Science process skills data was obtained from the average observation results using the science process skills rubric during the experimental and post-test. Data on science process skills for each change of topic has a specific value. Based on the value of each topic, it was found that students' science process skills for each topic had increased. The increase in science process skills for each topic is presented in Table 3. The average experimental post-test score increased compared to the average score during the experiment. This increase occurred in both experimental and control classes. The increase in the average score from observations during the learning process and the exploration post-test is presented in Table 4.

Before testing the hypothesis, a prerequisite test is carried out on data on students' mastery of physics concepts and science process skills, including normality, variance homogeneity, variance-covariance homogeneity, and linearity tests. The prerequisite test results show that both data are normal, homogeneous when tested individually, homogeneous when tested together, and the two variables are mutually linear.

The MANOVA (multivariate analysis of variance) test was used to test the first hypothesis. Based on the results of the MANOVA test, there were differences between students who studied with the 5E learning cycle accompanied by a link map (experimental class) and students who studied with the 5E learning cycle (control class). The second hypothesis testing was carried out using the Tukey test. Based on the results of the Tukey test, it is known that the class that studied with the 5E learning cycle accompanied by a link map had a higher mastery of physics concepts than the class that studied with the 5E learning cycle alone. These results follow research

Table 2. Data description of students' mastery of physics concepts and science process skills.

Parameter	Experimental Class		Control Class	
	PK	KPS	PK	KPS
Number of students	64	64	64	64
Average value	86.72	92.42	82.66	88.44
Minimum value	70	83,33	60	78,70
Maximum value	100	100	100	100
Standard deviation	7.62	4.93	9.08	5.803

Table 3. Increase in science process skills for each topic.

Class	Topic		
	Elasticity	Spring Vibration	Simple Harmonic
Experimental	83.16	88.19	96.70
Control	78.39	82.03	85.33

Table 4. Increase in values during the experiment and post-test.

Class	During Experiment	Post-test Experiment
Experimental	89.35	95.49
Control	81.92	94.97

conducted by Ahda (2012), which states that link maps are effective in helping students understand and remember the concepts discovered. Their connections can last a long time in students' memories. Research conducted by Amiroh (2014) also shows that link maps can help learning achievement for students with low initial abilities. The results of research conducted by Lindstroøm and Sharma (2009) and Lindstroøm and Sharma (2011) also show the benefits of link maps in helping students learn physics.

Students' mastery of concepts is seen from students' ability to link concepts both in the pre-explanation and elaboration phases. Even though the link map between concepts created by students looks like a mind map, the connection between the concepts created by students is evident. Through the concept linkage maps they create, it can be interpreted that students have been able to form their knowledge. These results also strengthen by Suparno (1997), which states that student's ability to form knowledge can be seen from students' skills when linking initial concepts and new concepts. Meanwhile, students who study without a link map do not get the opportunity to visualize how the concepts are related, so it is not easy to know whether students have mastered the concepts they have learned or not.

The link map also helps students understand and remember the concepts they have learned. Students in classes who study with link maps can use the link maps they have created to solve problems given by the teacher in the elaboration phase. In the problem-solving process, students are guided to remember and understand the concepts they have acquired and how they are related. By visualizing pieces of knowledge, link maps can help reduce the burden on the brain in storing memory. So that students can still remember old knowledge even though they have gained new knowledge. Pieces of knowledge that are well arranged and form a schema will influence a person's long-term memory (Slavin, 2012). It causes students who study with a link map to more easily remember what they have learned (Ong & Borich, 2006), making it easier to solve the problems obtained.

Students' inability to solve problems with cognitive aspects C2 (understanding), C4 (analyzing), C5 (evaluating), and C6 (creating) is because students in the control class were not allowed to visualize the relationship between the concepts obtained so that the concepts they know is partial. Partial concepts without visualization cause most students to forget their acquired concepts. It affects the process of solving problems for questions that require mastery of concepts. It often causes students to get trapped by questions and get wrong answers. This result also follows Ding, Reay, Lee, and Bao (2011) and Hegde and Meera (2012) that students tend to immediately calculate using formulas without understanding the physics concepts more thoroughly first.

The results of the third hypothesis test using the Tukey test show that students who study with the 5E learning cycle strategy accompanied by a link map have higher science process skills than students who study with the 5E learning cycle alone. Students who learn with a link map are ready to carry out experimental activities in the exploration phase. The link map makes it easier for students to understand the initial concepts (Hilger, Moreira & Griebeler, 2012) that the teacher gave in the engagement phase. Understanding initial concepts indirectly shapes students' readiness to discover concepts in the experimental phase. It is demonstrated by the student's ability to correctly fill in the empty columns in the link map. The link map also provides a detailed description of the concepts to be searched for. A detailed concept description can focus students' attention on the studied topic (Buzan, 2007). Ausubel, Novak, and Hanesian (1978) states that understanding initial concepts can direct students to the material to be studied and help them recall-related information that can be used to help embed new knowledge. It is in accordance with the link map function expressed by Lindstrøm and Sharma (2011), where a link map is a map of the relationships between concepts that functions as a means of forming knowledge and overcoming difficulties in understanding physics concepts (Kuan, 2010).

Students' readiness to discover concepts can make it easier to carry out exploration activities. It can train students' science process skills in classifying appropriate examples and predicting what will happen. Skills in classifying and predicting are the basis for developing skills in determining variables, compiling hypotheses, conducting experiments, interpreting data, compiling graphs, and concluding (Rezba, Sparague & Fiel, 2003). Therefore, students' science process skills in classes that study with the 5E learning cycle accompanied by a link map are better than those with the 5E learning cycle alone. Excellent science process skills will save more time so that experimental activities can be completed quickly and precisely.

The results of the data analysis also show that students' science process skills in both classes increased in each experiment (Table 4). It can be seen from students' ability to determine experimental variables, formulate hypotheses, conduct experiments, interpret data, compile graphs, and draw conclusions, which increases with each experiment phase. The average value of students' science process skills increased in both classes that studied with a link map and without a link map.

The first indicator of science process skills assessment is measured based on how students determine experimental variables. On student worksheets, the teacher presents reading and poses problems to students. Based on this problem, students are asked to determine the independent and dependent variables. In the spring force experiment, several students from both classes were still unable to differentiate between the independent and dependent variables. In the spring vibration experiment, students have begun to understand the meaning of the independent and dependent variables, so they experience an increased understanding of determining variables. That follows Etkina et al. (2006), which states that continuous problem analysis can make students understand the existing information. The information in question is information about the variables presented in the problem.

The second science process skills assessment indicator is carried out during the hypothesis preparation phase. In the spring force experiment, almost all students needed help understanding what was meant by hypothesis, so they only wrote research hypotheses with short formulas. In the next experiment, students can make hypotheses well, scientifically, and can be proven by experiments. These results are in accordance with Etkina et al. (2006), who stated that the more often students carry out scientific activities, the more their ability to make hypotheses will increase.

The third indicator of science process skills assessment is conducted when students conduct experiments. In this phase, overall, students have been able to carry out experiments correctly and according to the instructions. However, students still need clarification about determining the 0 (zero) point in measuring the increase in spring length after a load is applied. However, this difficulty no longer occurs in spring vibration and simple harmonic motion experiments. Students are more independent when carrying out experiments, and experimental activities take place more quickly than before.

The fourth science process skills assessment indicator is carried out when students interpret data as experimental results. In the spring force experiment, students still needed clarification in filling in the data obtained from the calculation results. When calculating the spring constant, students need to be more careful, so mistakes often occur between the initial length of the spring and the increase in spring length. However, these difficulties no longer appeared when they carried out a simple spring and swing equivalent experiment. Students begin to understand what they must do when interpreting data. These results follow Etkina et al. (2006), who stated that student activity in experimental activities can make students more careful in collecting data.

The fifth science process skills assessment is carried out during the graph preparation phase. In the force spring experiment, both classes still needed clarification about determining the scale on the graph. That happened again during the graphing phase of the spring vibration experiment. The results of the student's work on the student worksheets show that the scale on the graphs they made is still incorrect. In a simple swing experiment, students could make the scale correctly.

The sixth science process skills assessment is carried out when the phase concludes. In the spring force experiment, the conclusions made by students in both classes were not related to the hypothesis. In spring vibration and simple harmonic motion experiments, the conclusions made by students are related to the hypothesis. These results are in accordance with Etkina et al. (2006), who stated that scientific activities make students accustomed to evaluating experimental results through previously proposed hypotheses.

CONCLUSION

Implementing the 5E learning cycle strategy accompanied by a link map and 5E learning cycle, significantly influences students' mastery of physics concepts and science process skills. Students who study with the 5E learning cycle accompanied by a link map gain better mastery of concepts than students who study with the 5E learning cycle. Students who study with the 5E learning cycle accompanied by a link map obtain better science process skills than those with the 5E learning cycle.

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AUTHOR CONTRIBUTIONS

All authors contributed to the conception and design of the study, data collection, analyze, interpretation, writing, and revision of the manuscript. All authors approved the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

Regarding the research, writing, and publication of this paper, the authors state they have no competing interests.

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