Development of Learning Activities for Solving Physics Problems by Applying Rojas' Concept of Rectilinear Motion for Grade-10 Students

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Received: 7 November 2017; Accepted: 10 January 2018

Abstract

The purposes of this research were: 1) to create a set of learning activities for solving physics problems based on Rojas Concept of Rectilinear Motion; 2) to verify the quality of the learning activities and establish the effectiveness index of the learning activities; 3) to compare students' learning achievement and ability to solve physics problems before and after using those learning activities; and 4) explore the ability of the students to solve physics problems qualitatively. The participants in this research were 39 Grade-10 students at Sukhothai Wittayakom School, selected by Cluster Random Sampling. The research instruments included the lesson plans, a physics learning achievement test, a test of the students' physics problem solving ability, and a student behavior observation form. The data was analyzed by using a t-test for dependent samples and content analysis. The findings were as follows:

1. There were five lesson plans: (1) quantities of motion; (2) the speed measurement of rectilinear motion; (3) acceleration; (4) the relationship of speed, graph, time, and distance; and (5) equations for calculating quantities of motion. These lesson plans were considered appropriate at a high level ($\overline{x}$ = 4.43, S.D. = 0.23), and the effectiveness index of the learning activities was 0.7674.

2. The learning achievement and ability of the students after using these learning activities were found to be higher than before using the learning activities. The difference was significant at $p > .05$. The students were able to write the physics symbols correctly, describe the principles and equations of physics in problem solving, plan a solution systematically, carry out the plan correctly and completely, explain the connection between the results and the problems, check the answers, and explain how to apply this knowledge gained these learning activities to use in their daily lives.

Keywords: Physics Problem Solving, The Concept of Rojas

Introduction

Physics is a scientific field that studies physical phenomena and explains changes in those phenomena that occur around us and have important roles in our daily lives. It is considered to be an important and significant subject in the education system, yet, according to the Ordinary National Education Test (O-NET) results of Mathayomsuksa-6 students for physics in the academic year 2015, the average points was low, at 17.35% (a report from O-NET Test). This indicates that the teaching and learning of physics is not as successful as hoped and expected.

Physics questions address real-life situations and scenarios are addressed as problems through the form of written texts and numbers that students have to solve mathematically. Therefore, students must apply their knowledge of both physics and mathematics to solve these problems. However, it has been found that students mainly learn and practice physics problems by calculating mathematics, but they ignore rules and theories of physics. Additionally, they apply equations to find the answers without checking the relationship between the principles and theories in physics. This is an inefficient approach to solve physics problems (Dufresne, Gerace and Leonard, 1997, p. 270). Compounding the problem is the fact that many students have poor calculation skills that are necessary for solving physics problems (Rojas, 2010, p. 22). Given this, it remains an open question:

How should teachers approach the teaching and learning tasks to educate their students to solve physics problems efficiently?

Rojas (2010, pp. 22-28) proposed the concept of applying Polya's 4-step problem-solving technique (Polya, 1957, pp. 6-19) to solve physics problems, modified as six steps, explained as follows:

1) Understand the problem: it is necessary for students to know exactly what the question is actually asking.

2) Clearly explain and understand all aspects of the problem: students must write down all the rules, principles, and formulae of calculation required for solving the physics problem.

3) Plan the solution process: students must consider the problem, write down and plan the necessary processes to solve the problem.

4) Follow the plan: students must follow the planned processes to solve the problem.

5) Check the congruence in the equation: students should recheck the results to ensure that they are in accordance with the question posed

6) Check and evaluate their problem solving approach: students should evaluate their results and compare their processes with their companions to explore the best procedure for achieving the correct results.

After consideration of Roja's 6-step approach, this researcher felt that applying this concept to the teaching and learning of physics could enhance students' achievements and give them a greater capability of problem solving in their daily lives. The approach orderly defined in those six steps enables the students to achieve the goal of solving not only physics problems but also problems in their daily lives.

Objectives of the Research

1. To create, check and find an index of the efficiency of learning activities for solving physics problems on the subject of rectilinear motion, conducted for Grade 10 students, by adapting Rojas' concept.

2. To study the learning outcomes from these learning activities.

2.1 To quantitatively compare the learning achievement of the students in the subject matter by comparing the students' pretest and posttest results.

2.2 To quantitatively compare the physics problem solving ability of the students, by comparing the students' pretest and posttest results.

2.3 To qualitatively evaluate the ability of the students in solving physics problems by comparing the students' pretest and posttest results.

Research Methodology

The participants in the research project were 39 Grade-10 students at Sukhothai Wittayakom School, selected by Cluster Random Sampling.

The researchers adopted Rojas' 6-step approach previously described and applied it to the design of the learning activities for solving the physics problems on the topic of rectilinear motion. The research methodology was divided into 2 steps.

Step 1: The researchers created, checked and searched for the efficiency index of the learning activities to be applied in solving the physics problems. Following this, the learning activities were created, evaluated and checked by five experts in learning and classroom management. After the researchers had corrected the procedure as

suggested by the experts, a set of learning activities were created, checked and evaluated for suitability by the experts, including a secondary school physics teacher, two university lecturers in physics, a university lecturer expert in curriculum and instruction, and a university lecturer expert in assessment and evaluation. Additionally, the activities were checked and evaluated according to five aspects of Rojas's concept, namely, objectives, subject matter, learning activities, media and learning resources, and assessment and evaluation. The learning activities were tested for the efficiency index with the participating students. The instruments for the test were: 1) Defined learning activities for solving the physics problems of rectilinear motion; 2) an achievement test in physics about the rectilinear motion; and 3) an ability test about solving physics problems. All of the instruments were checked for index of item objective congruence, difficulty index, discrimination and reliability. Subsequently, they were used to analyze the data for finding the activity's efficiency index by using one group pretest – posttest design.

Step 2: The achievement and ability before and after conducting the learning activities were explored by the researchers. The research process was:

1) The students were asked to take an achievement test in physics about the rectilinear motion and an ability test about solving physics problems (multiple-choice test) as a pre-test.

2) The researchers provided the learning activities for solving physics problems, based on Rojas's Concept, regarding the rectilinear motion.

3) After having the learning activities, the students were asked to take an achievement test in physics about the rectilinear motion and an ability test about solving physics problems (multiple-choice test) again as a post-test.

4) The researchers compared the students' scores, before and after having learning activities, by using t-test for dependent Samples.

5) The researcher explored the ability for solving physics problems of rectilinear motion, based on Rojas's concept, qualitatively by using an observation form.

Data Analysis

Step 1: The researchers created, checked the quality and search for the efficiency index of learning activities about physics problem solving, adapting from Roja's concept about the rectilinear motion, conducted for the Grade-10 students.

1.1 Regarding the learning activity, the researchers created 6-step physics problem-solving learning activity, applied from Rojas's concept: 1) understanding a physics problem; 2) explaining aspects of the problem; 3) planning for solving; 4) following the plan; and 5) checking the congruence in equation, 6) check and evaluate the answer. Moreover, the researchers originated five plans of learning activity, namely: 1) quantities of motion; 2) the speed measurement of rectilinear motion; 3) acceleration; 4) the relationship of speed graph, time and distance; and 5) equations for calculating quantities of motion.

1.2 It was found that overall, both learning activity and instruction plans were very appropriate at high level ($\bar{x}$ = 4.43, S.D. = 0.23) as demonstrated in Table 1 below.

Table 1 The suitability of components of learning activity and instruction plans for solving physics problems adapted from Rojas's concept

Aspects	$\bar{x}$	S.D.	Suitability
1. Learning Objectives	4.20	0.26	High
2. Subject Matter	4.50	0.50	Very High
3. Learning Activity	4.30	0.40	High
4. Media and Learning Resources	4.53	0.37	Very High
5. Assessment and Evaluation	4.30	0.40	High
Average	**4.43**	**0.23**	**High**

1.3 The results showed that the efficiency index was at 0.7674, which was more than 0.5. This means that the activity was efficient and the students could increase their knowledge at 0.764 or 76.74%.

Step 2: The researchers studied the results of the activity about physics problem solving, adapted from Rojas's concept about the rectilinear motion conducted for the Grade-10 students.

2.1 The results showed that the score of posttest achievement was statistically significantly higher than the pretest at 0.05 as demonstrated in Table 2.

Table 2 The achievement results of the comparison between pretest scores and posttest scores by using the learning activity (n = 39)

Testing	$\bar{x}$	S.D.	$\bar{d}$	$S.D._d$	t	Sig.
Pretest	6.35	1.56	7.95	2.77	17.91*	.000
Posttest	14.31	2.44				

2.2 It was found that the posttest score was significantly higher than the pretest score at 0.05 as shown in Table 3.

Table 3 The results of the comparison of the students' ability to solve physics problems between pretest and posttest scores (n = 39)

Testing	$\bar{x}$	S.D.	$\bar{d}$	$S.D._d$	T	Sig.
Pretest	3.63	0.61	12.92	0.81	100.22*	.000
Posttest	16.55	0.55				

2.3 The results of evaluating the effect of following six steps of the students' ability to solve physics problems.

Step 1: Understanding the physics problem: It was found that the students could identify correct symbols for physical quantities and explain what quantities they should find more to solve the problems effectively.

Step 2: Explaining the problems: It was found that the students could explain principles, laws, and theories concerned with the physics problem, and then could demonstrate using correct formulae for calculating the results.

Step 3: Planning for problem solving: The finding was that the students could effectively plan a systematic approach to finding solutions and clearly explain the approach.

Step 4: Following the plan: The students demonstrated that they could follow the plan appropriately and completely.

Step 5: Checking for congruence in the equation: The students could correctly explain the connection between the expected answer of the problems and the results that they found by themselves. Moreover, the students

could explain the congruence between the units of measurement used in their own results and the ones indicated in the expected results.

Step 6: Check and evaluate the answers attained: The answers to the physics problems were provided to the students who were able to explain: what they had learned from the lessons about the rectilinear motion; how they could apply principles, rules and theories in their daily lives; and how they could creatively utilize their knowledge with problem solutions on the rectilinear motion.

Discussion

1. The five experts agreed on the quality of the overall plans of the learning activity, assessing its suitability at a high level ($\bar{x}$ = 4.43, S.D. = 0.23). These plans were created by the researchers after studying the education core curriculum in 2007, as stated by the Department of Physics and the Physics Teachers Manual 1 created by the Institute for the Promotion of Teaching Science and Technology (IPST). The researchers also studied research papers, and reviewed the literature, related to physics problem solving based on Rojas's concept. The information found when undertaking these activities informed the researchers when specifying the activity frame, designing the activity and creating the forms of measurement and assessment. These specifications were considered by the advisor and checked by the experts, and were subsequently modified and improved in accordance with the suggestions of the advisor and the experts. The efficiency index was calculated on the final activities plan.This was in accordance with the recommendations of Weil and Joyce (1978, pp. 11-25) regarding quality checking of the plans prior to conducting the learning and teaching activities.

Following the completion of the problem solving tasks by the students, it was found that the efficiency index was 0.7674. This indicated that the researchers had systematically developed the activity, evolved it step-by-step according to principles and theories, and designed the harmonious procedure of the activity from the first step to the last one. These processes were in accordance with Khammani (2010, p. 220) who summarized that the development of learning and classroom management processes ought to be proved through the processes of managing systematic composition by concerning theories and principles, including having relating composition to enhance the students to achieve their goals.

2. The results of conducting the learning activities are as follows.

2.1 The posttest scores were significantly higher than the pretest score at $p > 0.05$. This is because the process of solving physics problems based on Rojas's Concept encourages students to be able to solve physics problems effectively. The students could achieve the goal for solving physics problems in two ways. Firstly, students need to know and understand the concept, theory, and physics rules. Secondly, students need to have strategies for using the concept, theory, and physics rules to solve physics problems correctly. In addition, they need to have a calculation skill for mathematical equation (Portoles & Lopez, 2008). It can be said that the process of solving physics problems based on Rojas's Concept makes students understand physics rules and plan for their problem solution effectively. This notion is also related to the concept proposed by Pratontep (2012) who noted that the key to learn physics is to try to find the answer and explain the relationship of quantities by using mathematical equation (Pratontep, 2012).

2.2 The comparison between pretest scores and posttest scores of the students showed that the students' abilities in solving physics problems were statistically significantly increased at $p > 0.05$. These results support the thesis that Rojas's Concept, and the 6-step approach is an effective approach to enhance learning. This was

because the learning activity adapted from Rojas' concept was procedural and continual. It is related to activities developed from Polya's 4-step problem solving process suitable for solving physics problems. The activity could assist the students to find the results of the problems by using principles, laws, including theories of physics, mathematics knowledge and arithmetic calculation. Moreover, the students could apply the knowledge in their daily lives. As Saksuparb (2013) stated, the students used their knowledge, thought and experience through systematic processes from the beginning step to understand problems and solve them as expected. The result was also in accordance with the research conducted by Celcu, Couhgan and Eral (2007 as cited in Saksuparb, 2013, p. 146) which looked for 37 students' ability of solving physics problems. This is enhanced with Polya's techniques of problem solving processes, and the result was that the ability of solving problems with Polya's techniques was significantly higher the students' with normal instruction at 0.05.

2.3 Regarding the exploration of the ability in solving physic problems, it was found that the students were able to solve the problems effectively. The learning activities were designed systematically. Firstly, the researchers designed the learning activities by writing physics symbol with physics quantities before starting solving physics problems. As a result, students understand more clearly, and this leads students to be able to write physics symbol with physics quantities correctly. Moreover, they can tell what quantities need to be added for the complete result. Second, the researchers asked questions about principles, rules and theories about physics related to other important information of those questions. Then, the researchers explained the answers and discussed them with the students. This leads students to understand the principles, rules and theories about physics and be able to write the equation based on those principles, rules and theories. Thirdly, the researchers designed the learning activities by letting students plan how to solve the problems themselves. Therefore, students can practice planning solving the problems and explain the knowledge about mathematics used in solving the problems. Fourthly, since these students had to plan for their problem solution by themselves, they could solve the problems systematically and correctly. Next, in solving physics problems, students had to check the relationship of equations and explain the relationship between the question and the answer. Lastly, the learning activities encourage students to check the answers and explain how they make use of physics principles in their daily lives. When students frequently did these learning activities, they showed higher scores of an ability test about solving physics problems (the post-test) than the pre-test.

Research Recommendations

Recommendations for Application

1. Teachers should study Rojas's concept and the 6-step approach to solving physics problems in order to plan and prepare instructional materials, including learning activities suitable for the learning context.

2. Teachers should always consider the students' level and type of prior knowledge to check whether they are ready for doing problem-solving activities such as the knowledge of mathematics theories and calculations to solve physics problems.

Recommendations for Further Studies

1. Further research is recommended and suggested by assessing the learning achievement and abilities on solving physics problems to meet the passing criterion determined by teachers.

2. A significant set of learning activities for solving physics problems should be developed for all secondary school levels and linked to Rojas's concept. This should allow students to improve personal learning processes for solving physics problems presented in physics subjects at all levels.

Acknowledgement

I would like to express the deepest appreciation to my advisor, Associate Professor Dr. Pakorn Prachanban for his devotion and valuable suggestions throughout the research project. I am extremely grateful to all of the experts for their many suggestions and corrections that has enabled me to complete my research efficiently and effectively. Additionally, I would like to thank the school director together with the teachers and the students at Sukhothai Wittayakom School for their participation and cooperation in facilitating the research and the data collection. Above all, I am extremely thankful to my parents for their remarkable support. Also, I would like to dedicate the research to all my benefactors. I present this research report with confidence and hope that this research will contribute to the improvement of education and for the information of those others who are interested.

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