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Effect of Tutorial Giving on The Topic of Special Theory of Relativity in Modern Physics Course Towards Students' Problem-Solving Ability

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Abstract. A Special Theory of Relativity handbook has been successfully arranged to guide students tutorial activity in the Modern Physics course. The low of students' problem-solving ability was overcome by giving the tutorial in addition to the lecture class. It was done due to the limited time in the class during the course to have students do some exercises for their problem-solving ability. The explicit problem-solving based tutorial handbook was written by emphasizing to this 5 problem-solving strategies: (1) focus on the problem, (2) picture the physical facts, (3) plan the solution, (4) solve the problem, and (5) check the result. This research and development (R&D) consisted of 3 main steps: (1) preliminary study, (2) draft I product development, and (3) product validation. The developed draft product was validated by experts to measure the feasibility of the material and predict the effect of the tutorial giving by means of questionnaires with scale 1 to 4. The students problem-solving ability in Special Theory of Relativity showed very good qualification. It implied that the tutorial giving with the help of tutorial handbook increased students problem-solving ability. The empirical test revealed that the developed handbook was significantly affected in improving students' mastery concept and problem-solving ability. Both students' mastery concept and problem-solving ability were in middle category with gain of, 0.31 and 0.41, respectively.

1. Introduction

Special theory of relativity consisted of the following topics: Newtonian relativity, Einstein's postulates, Lorentz coordinate transformation, simultaneity and the relativity of time, length contraction, time dilation, twins paradox, relativistic doppler shift, Lorentz velocity transformation, relativistic momentum and relativistic energy [1,2,3].As the matter of fact, many students face difficulty in solving problems on the topic of the special theory of relativity. When the students were given problems that were slightly different from the given examples, they are generally unable to solve those problems. Therefore, it is important to introduce explicit solving strategy-based tutorial to help students' difficulty in solving problems.The tutorial underlines the systematic strategies to solve the problems. It does not only stress on the "given" and "questioned", but also lay emphasis on (1) focus on the problem, (2) picture the physical facts, (3) plan the solution, (4) solve the problem, and (5) check the result [4]. An excellent approach to increase the students problem-solving ability is tutorial giving [5,6]. A tutorial is learning and instruction program to help students during taking lectures by means of guided self-learning.

Some previous studies showed that to simultaneously (a) make students become effective problem solvers and (b) master the concepts are a two-goal that is hard to reach. Even by instructional model,

there are still many students find difficulties in solving problems [7], and their mastery concepts are relatively low [8]. Combining the active learning and problem-solving strategies to the modern physics students can enhance the students mastery concept and their problem-solving ability [9,10]

This research and development are mainly aimed to (1) develop tutorial handbook on the topic of Special Theory of Relativity, (2) investigate the effect of the tutorial giving on the students mastery concept, (3) investigate the effect of the tutorial giving on the student's problem solving ability, and (4) measure the student's problem solving ability at Special Theory of Relativity.

2. Material and Method

2.1 Development Tutorial Handbook

To develop tutorial handbook product, a research design by means of research and development (R&D) was applied. Basically, there are 3 main steps for R&D approach [11]: (1) preliminary study which consists of literature study and survey, (2) product development in terms of draft product arrangement, judgment (expert validation), and trial field testing, (3) product validation. In this present study, we only restricted to the step (1) and (2).

The experimental procedures are described as follows: (1) preliminary study; in this step, an investigation was focused on the learning problems that were faced by students during taking the modern physics course. From the investigation, it was known that 80% of the students found difficulties in solving problems of modern physics. According to this preliminary study, a handbook to guide students in the tutorial was then chosen to implement. (2) draft product development; in this step, a tutorial handbook was created with the following 10 component specifications: (a) introduction, (b) learning objectives, (c) explanation, (d) problem examples and the solutions based on 5 explicit solving strategies, (e) summary, (f) problems, (g) solutions to the problems, (h) scoring method for problem solving, (i) physical constants and important, and (j) references. The tutorial handbook was also completed with "for readers" section in order to help students be easy to use and learn. (3) judgment (validation by experts); this is an assessment activity to evaluate the developed tutorial handbook. This was done to increase the theoretical validity of the products. The judgment was done by 2 physics experts by means of 1-4 scoring scale questionnaires. 4 means very feasible, 3 means feasible, 2 means less feasible, and 1 means unfeasible. The judgment was performed before the trial field testing. (4) trial field testing; in this step, the tutorial handbook was tried to limit the number of students to know the students responses including clarity of language usage, a sequence of materials, consistency of notation usage, availability of images to make the concept clearer. The students responses to the tutorial handbook content were gathered by questionnaires with scale 1 to 4; 4 = excellent, 3 = good, 2 = fair, and 1 = poor. The vision for the final product was based on the students' responses.

The collected data in this present study are material feasibility, students' response, and problem-solving ability. The value of the data was analyzed by the following mathematical expression.

$$N = \frac{SD}{SM} \times 100 \quad (1)$$

where N = grade, SD = score, dan SM = maximum score.

The grade criteria for those data are given bellow.

85-100 = Excellent
75- 84,9 = Good
65 – 74.9 = Satisfactory
55 – 64.9 = Poor
< 55 = Worst

2.2 Trial Field Testing of Tutorial Handbook

The effect of tutorial giving on the students' mastery concept and problem-solving ability was evaluated by means of Pretest-Posttest Control-Group Design [11] and designed as depicted in Table 1.

TABLE 1. Quasi-experimental Design of Pretest-Postes Control-Group

Group	Pretest	Treatment	Posttest
E	X_1	T	Y_1
C	X_2		Y_2

E = Experimental group
C = Control group

X_1 = Pretest score for experimental group
X_2 = Pretest score for control group
Y_1 = Posttest score for experimental group
Y_2 = Posttest score for control group
T = Treatment by tutorial giving

Acceptance/rejection of null hypothesis is based on the criteria as given in Table 2.

TABLE 2. Acceptance/rejection of the null hypothesis

Group	t-test result	α=0,05 db = N_1+N_2-2	Note
Pretest Exps.-control	t_0	$-1.998 < t_0 < 1.998$	H_0 is accepted (H_a is rejected)
Posttest Exps.-control	t_0	$-1.998 < t_0 < 1.998$	H_0 is accepted (H_a is rejected)

The amount of increment of the students' problem-solving ability was analyzed by average normalized gain, i.e. the ratio of average actual gain and maximum of average gain given by the following equation[12]:

$$< g > = \frac{\%<\boldsymbol{gain}>}{\%<\boldsymbol{gain}>_{\boldsymbol{max}}} = \frac{\%<posttest>-\%<pretest>}{100-\%<pretest>} \quad (2)$$

With category:
$< g >$ is high for $< g >$ larger than 0.7
$< g >$ medium for $< g >$ of 0.3 to 0,7
$< g >$ low for $< g >$ smaller than 0.3

3. Experimental Results and Discussion

3.1 Expert Validation Result

The draft of the special theory of relativity handbook was validated by 2 experts to examine its feasibility. The validation result is depicted in Table 3.

TABLE 3. Validation Result for Material Feasibility & Its Prediction

Sub	Component	Score	Maximum Score	Grade	Qualification
1	**MATERIAL FEASIBILITY**				
A	Introduction	7	8	87.5	Excellent
B	Learning Objective	16	16	100	Excellent
C	Content				
	1.1 Newtonian Relativity	44	56	91.7	Excellent Excellent
	1.2 Einstein's Postulates	24	24	100	Excellent Excellent
	1.3 Lorentz Transformation	45	48	93.8	
	1.4 Synchronized Clock and Simultaneity	38	40	95	Excellent Excellent
	1.5 Length Contraction				Excellent Excellent
	1.6 Time Dilation	45	48	93.8	Excellent Excellent
	1.7 Twins Paradox	38	40	95	Excellent
	1.8 Relativistic Doppler Effect	37	40	92.5	
	1.9 Lorentz Velocity Transformation	38	40	95	
	1.10 Relativistic Momentum	39	40	97.5	
	1.11 Relativistic Energy	46	48	95.8	
		38	40	95	
Sub	Component	Score	Maximum Score	Grade	Qualification
D	Examples and Explicit Solutions	54	56	96.4	Excellent
E	Summary	16	16	100	Excellent
F	Problems	29	32	90.6	Excellent
G	Solutions to Problems	24	24	100	Excellent
H	Problem Solving Scoring	24	24	100	Excellent
Average				95.5	Excellent
2	**Effect Prediction**				
A	The whole content of the tutorial handbook may make students' opportunity exercise to solve problem systematically and structurally following the given 5 steps of problem-solving	8	8	100	Excellent
B	The whole content of the tutorial handbook may	8	8	100	Excellent

	give raise students' problem-solving ability				

According to the validation result, it can be inferred that the average material feasibility was 95.5 with excellent qualification. The effect prediction of the tutorial giving on providing an opportunity to the students to exercise to solve problem systematically and structurally following the given 5 steps of problem-solving was 100 with excellent qualification. The effect prediction of the tutorial giving on the students' problem skill ability was perfectly 100 with excellent qualification.

3.2 Students' Response Result

Students' response on the handbook content is given in Table 4.

TABLE 4. Students' Response on The Handbook Content and Its Effect Prediction

Sub	Component	Score	Maximum Score	Grade	Qualification
1	**HANDBOOK CONTENT**				
A	Introduction	32	40	80	Good
B	Learning Objective	35	40	87.5	Excellent
C	Content				
1.1	Newtonian Relativity	135	160	84.4	Good
1.2	Einstein's Postulates	65	80	81.3	Good
1.3	Lorentz Transformation	141	160	88.1	Excellent
1.4	Synchronized Clock and Simultaneity	106	120	88.3	Excellent
1.5	Length Contraction	135	160	84.4	Good
1.6	Time Dilation	107	120	89.2	Excellent
1.7	Twins Paradox	103	120	85.8	Excellent
1.8	Relativistic Doppler Effect	103	120	85.8	Excellent
1.9	Lorentz Velocity Transformation	101	120	84.2	Good
1.10	Relativistic Momentum	140	160	87.5	Excellent
1.11	Relativistic Energy	103	120	85.8	Excellent
D	Examples and Explicit Solutions	186	200	93	Excellent
E	Summary	69	80	86.3	Excellent
F	Problems	140	160	87.5	Excellent
G	Solutions to Problems	80	80	100	Excellent
H	Problem Solving Scoring	115	120	95.8	Excellent
	Average			87.5	Excellent
2	**EFFECT PREDICTION**				
A	The whole content of the tutorial handbook may make students' opportunity exercise to solve problem systematically and structurally following the given 5 steps of problem-solving	36	40	90	Excellent
B	The whole content of the tutorial handbook may give raise students' problem-solving ability	34	40	85	Excellent
C	The whole content of the tutorial handbook may make students' opportunity exercise to solve problem systematically and structurally following the given 5 steps of problem-solving	35	40	87.5	Excellent

Based on Table 4, it is clearly seen that the students' response on the special theory of relativity handbook content was 87.5 with excellent qualification. The effect prediction of the tutorial handbook on giving the students opportunity to exercise their problem-solving ability was 90 with excellent qualification. The effect prediction of the tutorial handbook on the students' motivation was 85 with excellent qualification. The effect prediction of the tutorial handbook on the students' self-learning was 87.5 with excellent qualification.

3.3 Students'Problem Solving Ability

Students' problem-solving ability in the special theory of relativity is tabulated in Table 5.

TABLE 5. Students' Probem-Solving Ability in Special Theory of Relativity

No.	Problem-Solving Ability	Average	Qualification
1	Problem focuses	84.5	Good
2	Physical fact picturing	66.3	Fair
3	Solution plans	100	Excellent
4	Problem-solving	93.3	Excellent
5	Result checking	95.8	Excellent
	Average	88	Excellent

From Table 5, the students' problem-solving ability in the special theory of relativity was on average of 88 sith excellent qualification. The excellent handbook feasibility indicated that the handbook has good reliability. Both experts and students were in good agreement that the handbook tutorial on improving students' problem ability had a positive effect, which were indicated by excellent qualification. Therefore, the tutorial giving can increase the students' problem-solving ability as previously proposed by Pride, et al.

3.4 Students'Mastery Concept

The effect of the tutorial giving on the student's mastery concept was evaluated by comparing their grades for the experimental and control classes as depicted in Table 6.

TABLE 6. Students' Grade for Conceptual Understanding in Special Theory of Relativity

No.	Aspect	Experimental Group	Control Group
1	Average Pretest	66.9	66.4
2	Average Posttest	77.3	69.2
3	Minimum Grade for Pretest	40.0	35.0
4	Maximum Grade for Pretest	85.0	85.0
5	Minimum Grade for Postest	65.0	40.0
6	Maximum Grade for Posttest	92.5	85.0
7	Increasing	10.4	2.8
8	Gain	0.31	0.08

From Table 6, it can be revealed that the experimental and control classes had the similar initial ability. The experimental and control groups had increased of conceptual understanding of 10.4% and 2.8%, respectively. The experimental group had a gain of 0.3 with medium classification, meanwhile the control group had a low classification. It is because the students in the experimental group had extra time to study during tutorial giving.The effect of the tutorial handbook usage on the increasing of the students' conceptual understanding was evaluated by t-test analysis, as summarized in Table 7.

TABLE 7. t-test Result for the Students' Conceptual Understanding in Special Theory of Relativity

Group	Average Posttest	$t_{calculation}$	t_t (α=0.05, db= 65)	Note
Experiment	77.3	4.14	1.998	H_0 is rejected (H_a is accepted)
Control	69.2			

Table 7 showed a significant different between the experimental and control groups in terms of the students' conceptual understanding. It revealed that the tutorial handbook usage in the modern physics course may give a positive effect on the students' conceptual understanding, even though in medium classification. It can be increased by means of providing students with the summary task before starting the class.

The effect of the tutorial giving on the student's problem-solving ability was evaluated by comparing their grades for the experimental and control classes as depicted in Table 8.

Table 8 Students' Grade for Problem Solving Ability in Special Theory of Relativity

No.	Aspect	Experimental Group	Control Group
1	Average Pretest	60.4	67.8
2	Average Posttest	76.5	65.2
3	Minimum Grade for Pretest	51.0	56.0
4	Maximum Grade for Pretest	74.0	74.0
5	Minimum Grade for Postest	64.5	39.8
6	Maximum Grade for Posttest	95.5	96.3
7	Increasing	16.1	-2.6
8	Gain	0.41	-0.08

According to the information in Table 8, the increasing of students' problem-solving ability in experimental group is 16.1% and control groups decrease 2.6%, respectively. It is because the more time available for students of the experimental group to do some exercises than that of the control group. The gain for the experimental group was 0.41, meanwhile, a negative value of gain was detected for the control group.

The effect of the tutorial handbook usage on the topic of the special theory of relativity on the students' increasing of problem-solving ability was evaluated by t-test as depicted in Table 9.

Table 9 t-test Result for the Students' Problem-Solving Ability in Special Theory of Relativity

Group	Average Posttest	$t_{calculation}$	t_t (α=0.05, db= 65)	Note
Experiment	76.5	3.95	1.998	H_0 is rejected (H_a is accepted)
Control	65.2			

The t-test result on the students' problem-solving ability in the special theory of relativity showed significance different between experimental and control groups. It revealed that the tutorial giving can give positive effect in increasing the students' problem-solving ability with medium qualification. More exercises can be given to the students to provide them better problem-solving ability.

4. Conclusion

A tutorial handbook on the topic of the special theory of relativity with excellent feasibility and response from students has been successfully developed. The tutorial handbook was arranged to increase students' problem-solving ability and mastery concept with excellent qualification. In addition, the tutorial handbook could motivate students to have self-learning awareness. The empirical t-test showed that the tutorial of the special theory of relativity assigned a positive effect to the students mastery concept and problem-solving ability. The students' mastery concept and problem-solving ability obtained a gain of 0.31 and 0.41 with medium classification, respectively.

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