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Transferring of Mathematics Knowledge into the Physics Learning to Promote Students' Problem-Solving Skills

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The main objective of this research is to determine the extent of effectiveness of transfer of mathematics knowledge-model in enhancing the students' ability of physics problem solving. In this collaborative study, a quasy-experimental method with non-equivalent control group pretest posttest design was carried out on 248 eleventh grade students of four public senior high schools (SMAN) in Pontianak-Westkalimantan, Indonesia. Experimental group consists of 125 students received instruction using the transfer of mathematics knowledge-model while the other group (123 students) serving as control was taught in conventional model. A Mathematics Prior Knolwedge Test (MPT) and a Physics Achievement Test (PAT) were developed to examine effect of the two treatments. A three-times instructional intervention on sound wave topic was implemented. The results revealed that transfer of mathematics knowledge did make students could solve the problems better than the conventional learning. It is also found that the understanding of mathematics prior knowledge could be a significant predictor to estimate students' problem solving competencies in physics.This study not only has enriched a significant perspective of problem solving in education, but also provided a clear insight regarding the implementation of transfer of mathematics knowledge into physics learning.

Keywords: transfer of learning, mathematics prior knowledge, problem-solving ability, metacognitive strategy, learning

INTRODUCTION

Due to the rapid and continuous change of new social, economic, communication, and environmental challenges, modern societies face various problems has led to the necessity for individuals to possess the skills to solve problems in the twenty-first century (Kretzschmar & Süß, 2015; Ewies et al., 2021). It means that problem solving and teamwork are becoming increasingly more important than the relevance of routine tasks. Therefore, educators in many countries have begun to focus their mathematics and science educational researches and practices to increase the skills that are necessary to handle these new challenges. Unlike the classical academic skills that mainly involve the memorisation and reproduction of specific information and knowledge, 21st century

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skills are more transversal, focusing on the acquisition, transfer of knowledge, and application of knowledge (Kereluik et al., 2013). The use of mathematics prior-knowledge enabled students to improve problem solving competency is a positive transfer (Sharma, 2013).

In educational practice, at a classroom level, Greiff et al. (2013) suggested some helpful instructional interventions should be done by teachers to promote students' skills of problem solving any subject-matter content, as follows: (1) The teacher should be able to create an atmosphere that supports students to explore, apply, and improve the skills they have learned; (2) The teacher should be able explicitly to teach, model, and promote the skills; (3) The teacher should be transfer knowledge from one domain to another into the curriculum to avoid having only domain-specific applications; (4) The teacher should integrate the 21st century skills into their instructions and implement the appropriate strategies. Involving students in science lessons may require pedagogical knowledge to implement various strategies e.g metacognitive strategy. Magaji (2021) argued that applying prior knowledge, modelling explicitly heuristic strategies, and eliciting feedback are vital problem-solving skills. It also allows teachers to gauge progress and minimize gaps in students' knowledge.

Many researchers have found the major barriers regarding the students' problem solving competencies in physics. Most students are unable to to apply mathematical knowledge to the concepts and principles of physics properly (Kereh, 2014; Obafemi & Ogunkunle, 2013; Butler & Coleoni, 2016). According to Robello et al.(2015) and Hollabaugh (2017), students who are unable to transfer of mathematics knowledge to physics, they are very likely not able to solve the problems. They are also lack of thinking strategies that appropriate to solve the problems *(*Fadel et al.,2016*;* Körhasan & Ozcan, 2015; Reddy & Panacharoensawad, 2017).

The two major obstacles as mentioned above e.g. lack of transfer of mathematics knowledge to physics and of thinking strategies will be main concerns of this study. Sharma (2013) claimed that students who have the skill of transfer of learning enable them could apply knowledge, abilities, habits, attitudes, or other responses from a situation they received to other situations that were not previously learned / new situations. In fact, the transfer of learning may be facilitated in social work education (Macaulay & Cree, 1999) and is a central issue in both education and learning psychology (Gentner et al., 2003), and an integral part of the learning process (Sharma, 2013). Stenger (2017) asserted that once a student has good transfer skills, he will have a great opportunity to change jobs or be able to play a role in his new career. Unfortunately, the study that integrating intentionally the transfer of knowledge in educational settings has not been much carried out (Simons, 1999).

Related to this study, wave sound is an essential topic (Walker, 2008) in the physics curriculum, especially topics of sound intensity and Doppler effect. The two topics demand highly ability to convert and interpret mathematics formulas, apply algoritm concepts, and link fraction concept. Unfortunately, the topics was regarded averagely by huge amount of eleventh grade students of public senior high schools as a quite difficult. In a meeting of the Physics Teacher Forum (*MGMP Fisika-SMA*) in Pontianak, the teachers reported that most students showed errors when administered the essay tests regarding the intensity of sound, level of sound intensity, and Doppler effect. Most of students overemphasized on recalling or memorizing of the physics formulas. So, if they were forgetting the formulas, they will not able to find the anwers. They are lack of applying and linking appropriate mathematics concepts and principles properly to solve the topic problems of physics. Moreover, they are not able to select the thinking strategies to solve word problems of the topics. Although some have sketched the graphic post-organizers (e.g arrows, free-body diagrams), but they were often not rechecking the final solutions. Simple stated, the students competency of problem solving of the topic is low. Obafemi & Ogunkunle (2013) also reported that mathematics abilities for supporting physics learning of senior high school students in many countries are low. These actual and contextual problems have triggered me for sharing some practical instructional interventions that transferring the mathematical knowledge in oder to solve problems of the sound wave topic.

Salame et al. (2022) argued that students who depend only on algorithmic or heuristic problem solving less likely to develop conceptual understanding of concepts and gain meaningful learning. In the context of this study, in order to promote transfer of knowledge, students were trained and modeled intentionally to; (1) remind the mathematical knowledge (facts, concepts, principles, and procedures or algorithms) that they have previously learned, (2) interpret them verbally, graphically, and symbolically, or vice versa; (3) explicitly apply and model procedures or algorithms to solve physics problems faced by students, and: (4) use mathematics knowledge to support rechecking of results if the final solution is plausible, meaningful, or intelligible.

This study is compliance with the actual and contextual problems the teachers faced in their schools and will suggest the practical improvements in learning physics. Therefore, this study conducted to increase senior high school students' ability to solve the wave sound topic is a quite rational. However, the investigations in order to gauge the influence of transfer of mathematics knowledge-model in enhancing the students' ability of physics problem solving had been not much conducted. The main objective of this research is to determine the extent of effectiveness of transfer of mathematics knowledge-model in enhancing the students' ability of physics problem solving. This study will also examine if students' prerequisite mathematics knowledge acquisition could be used a significant preditor of students' problem solving competency of physics.

METHOD

This collaborative research applied the quasy-experimental method with the pretest posttest non-equivalent control group design (Creswell, 2008). The target population is the total eleventh grade students of public senior high schools (SMAN) in Pontianak-Westkalimantan-Indonesia enrolled in the same (second) semester academic year 2021/2022. Sample of this study is 268 students consists of 125 students (as experimental group) and 123 students (as control group). The schools and classes as sample of this study were drawn by using intact group random sampling technique. The distribution of samples in experimental-control classes in this study is shown in Table 1.

Table 1
The distribution of number of samples per class

Schools	Experiment Classes	Control Classes
SMAN 1 Pontianak	XI MIA 1 (32 students)	XI MIA 2 (30 students)
SMAN 3 Pontianak	XI MIA 4 (29 students)	XI MIA 1 (32 students)
SMAN 6 Pontianak	XI MIA 3 (33 students)	XI MIA 2 (30 students)
SMAN 8 Pontianak	XI MIA 1 (31 students)	XI MIA 2 (31 students)
Total of students	125	123

Before conducting the investigation, I have invited the four volunteer teachers (as co-researchers) in 3-times nonformal meetings held at physics laboratory of Education Department of Education and Teacher Training Faculty (FKIP) Tanjungpura University-Pontianak. *At the first meeting*, we discussed to explore the possible causes of students errors or difficulties in solving problem of wave sound topic the teachers faced in the schools as base-line. *At the second meeting*, we discussed collaboratively about; (1) the items of the Mathematics Prior Knolwedge Test (MPT) strongly needed to solve problem of Sound Wave topic; (2) items of the Physics Achievement Test (PAT) of Sound Wave that have developed earlier; and (3) the teaching scenarios to apply the Transfer of learning model and Direct Instruction (conventional) model that have designed earlier. *At the last meeting,* I executed *the teachers training* by modelling explicitly the models for 3-times instructional interventions (treatments) regarding transfer of mathematics kowledge integrated with metacognitive strategies for experimental group and Direct Instruction (sonventional) model for control Group. Before giving the treatments, I asked the four teachers to select respectively one class as experiment group and one group as control group.

In the line of transfer of learning-model implemented in this study (adapted from Djudin, 2017), I operationalized the four phases in solving the problems of sound wave topic as follows:

Phase 1: Relating new knowledge to previous knowledge

- Remember to previous concepts and principles of physics they have learned
- Mention the prerequisite mathematics knowledge related to the physics

Phase 2: Selecting thinking strategies deliberately

- Read the text slowly to understand and sense the problems
- Choose the basic concepts of mathematics knowledges
- Interpret the physics concepts by using mathematical interpretations or vice versa

Phase 3: Planning and monitoring thinking strategy

- Sketch or draw the two dimensional-diagrams
- Make sure that the two dimensional diagrams have constructed are helpful
- Write the appropriate physics formulas or magnitude in International System Unit
- Execute the computations by using the basic concepts of mathematics knowledges to find a right final solution
- Monitor and make sure that all the operations or computations are correct

Phase 4: Evaluating thinking processes, checking the results

- Recheck that the procedures and computations are correct
- Write and interpret the final result based on the interpretations of physics
- Make sure that the solutions are correct by looking backwards

The total score of the Mathematics Prior-knolwedge Test (MPT) is 20 and Physics Achievement Test (PAT) is 100.00 before and after the treatment were pooled by using the parallel pre- and post-test. The MPT test consists of 20 items of three-options multiple choice test with the reliability coefficient of Kruder Richardson (KR-21) was 0.78. The PAT essay test consist of 5 items with the coefficient of Alpha Cronbach was 0.61. After administering the tests, no feedback was given to students. The pre-test scores were reserved for use after the post-test. Students were asked not to discuss their responses or solutions after the test.

The timeline of a three times instructional interventions (treatments) with 2 x 30 minutes each of sound wave topics implemented to the two groups (still in pandemic Covid-19 schedule) is shown in Table 2. The students who were absent during the treatments or pre-test and post-test administration were excluded from the data analysis.

Table 2
The timeline of treatments

Treatments	Experiment Classes	Control Classes
Pretest	MPT and PAT	MPT and PAT
Treatment-1	Sound Intensity	Sound Intensity
Treatment-2	Level of Sound Intensity	Level of Sound Intensity
Treatment-3	Doppler effect	Doppler effect
Posttest	MPT and PAT	MPT and PAT

The significant difference of the mean scores of the MPT and PAT before and after the treatments will be examined by using *t*- test. The extent of effectiveness of the model is assessed by using Cohen’s formula of Effect Size (ES) rate. To determine if prerequisite mathematics knowledges understanding is a positive predictor of students’ competencies in problem solving of physics, a linear regression analysis were applied.

FINDINGS AND DISCUSSION

The MPT and PAT scores from both groups were subjected to a normality test before applying the appropriate statistical analysis. Based on the Shapiro-Wilk test, the pre-test and post-test scores in the MPT and PAT assumed normal distribution so that suitable for appropriate parametric testing.

1. Mathematics Prior Knowledge Test (MPT)

a. Analysis of MPT Pretest and Posttest mean scores

Pretest mean scores between the Transfer of Learning Group (M = 6.51, SD= 0.66) and Non-Transfer of Learning Group (M = 6.24, SD = 1.00) were analyzed using two-tailed independent samples t-test. Results showed that the groups were significantly undifferent prior to the intervention [t (246) = 1.33, sig (p) = 0.189]. The MPT post-test mean scores of the two groups after the intervention were compared using independent samples t-test. Results showed that theTransfer of Learning Group (M=11.54, SD = 1.33) and the conventional Group (M=10.39, SD = 1.50) did differ significantly in the MPT [t (246) = 3.34, sig (p) = 0.001] (Table 3).

Table 3
Comparison of MPT Posttest Mean Scores

	N	Mean	SD	SE	df	*t*	sig.
Transfer of Learning -Model	125	11.54	1.33	0.226	246	3.34	.001*
Conventional Model	123	10.39	1.50	0.261			

**p < .05*

b. Analysis of MPT as a Predictor of Problem Solving Competency

Linear regression analysis showed that mathematics prior knowledge accounted for 12.10 % of the variations in the problem-solving competency post-test scores (R^2 = 0.121, t (124) = 3.68, sig (p) < 0.05). Results showed that students' mathematics prior-knowledge significantly predicted their level of problem-solving competency of entirely and selected sound wave topics (B = 0.66, sig (p) < 0.012). Its linier regression equation is $y = 10.10 + 0.116\,x$ (Table 4).

Table 4
Regression Analysis Summary for MPT Predicting Problem Solving Competency

Variable	B	95% CI	ß	*t*	Sig
(Constant)	10.10	[4.26, 15.98]		2.49	0.034*
MPT post	0.116	[0.52, 1.11]	0.66	3.68	0.012*

Note R^2 = .121, *p < .05 *CI = Confidence Interval for B*

This study concluded that the implementation of transfer of mathematics knowledge-model could enhance the students' ablity to transfer the mathematics prior-knowledge. This finding is also supported by the which revealed a conclusion that the prior knowledge of mathematics could be assumed as a positive predictor to estimate the physics problem solving competency.

The approach applied in this model adapted fom Dirkes (1985) as developed by Djudin (2017) was integrated with tranfer of mathematics knowledge at each step in a way. To promote transfer of knowledge, students were trained and modeled to; (1) remind the mathematics knowledge that they have previously learned, (2) interpret them verbally, graphically, and symbolically, or vice versa; (3) explicitly apply and model procedures or algorithms to solve physics problems faced by students, and: (4) use mathematics knowledge to support rechecking of results if the final answer is plausible, meaningful or intelligible.

The type of transfer that involves the use of mathematics prior-knowledge and has enabled students to improve his/her problem-solving competency is a positive transfer (Sharma, 2013). In addition, in solving problems, it is very possible for students to use mathematics knowledge directly related to physical problems encountered (eg determining the value and direction of observed frequency in Doppler effect) and may not be directly related (applying them in real situations), the transfer that might occur is horizontal and vertical transfer (Robello et al., 2015). The learners who able to link their prior knowledge to new learning and from learning to the application, they are likely to have good skills of transfer of learning. They will have a great opportunity to change jobs or be able to play a role in his new career (Simons, 1999; Stenger,2017) and could increase the speed of learning (Macaulay & Cree, 2007).

Stenger (2017) proposed 10 (ten) ways to improve transfer of learning in educational settings: (1) Concentrate on the interrelation of what you're learning to other areas; (2) Try to explain and self-reflect; (3) Use a variety of learning media; (4) Change things up as often as possible; (5) Identify any gaps in your knowledge; (6)Establish clear learning goals; (7) Practise generalising; (8) Make your learning social; (9) Use analogies and metaphors; and (10) Seek daily opportunities to apply what you've learned. In line with Stenger's proposal as mentioned above, I elaborated the ways in order to promote transfer of learning skills in implementing the instructional interventions in physics are described as follows:

First, identify the gap between what students should master in solving physics problems that will be given with what is learned and mastered the majority of students. The experience of teaching a teaching material will enable the teacher to identify the factors that cause difficulties, the form of mistakes made, and the failure of the lecturer to discuss a teaching material properly. Without a comprehensive understanding of the readiness of lecturers and students in solving problems, the transfer of learning will be difficult to practice and develop. Weisberg (2006) asserted that mastery of content knowledge is essential for applying teaching pedagogies in physics.

Second, focus on problem solving problems that are relevant to the physics concepts being studied. Students are expected to be able to relate what they learn to what they already know (through the apperception technique) and create new perceptual connections and long-term memory storage. Delivering learning objectives, their benefits to support further studies, and linking objectives to the context of real-life everyday life are important learning principles that are conveyed before solving problems (questions).

Third, reflect on yourself and answer yourself the questions that will be given. Problems given to students need to be studied first (self-reflection), for example related to the level of difficulty and suitability with what has been learned, and curriculum demands. This will be better if the lecturer does it first. With this strategy, it is believed that the time allocation required by students will be sufficient and in accordance with the context of the material being studied. In addition, the understanding and ability of lecturers to explain questions and solving strategies in their own words about certain teaching materials becomes better, and can develop knowledge transfer.

Fourth, explicitly train and model deliberately the steps in the problem-solving model used. There are many problem-solving strategies that have been applied in the physics learning process. However, the majority of education experts agree that thinking processes and skills (cognition and metacognition), and other skills, can undoubtedly be developed or enhanced through intentionally modelling and explicit training (Mahdavi, 2014; Koch, 2001; Zohar & Barizilai, 2013). Applying what the students have studied at school to daily problems takes a lot of practices (Stenger,2017) and educators should look for ways and opportunities to apply the knowledge everyday life (Sharma, 2013).

Fifth, use a multi-representation approach. Problems to be solved need using a variety of approaches and techniques. Interpreting mathematical symbols verbally or vice versa, demonstrating physical concepts and / or completion procedures using audio-visual and /

or ICT media, student and lecturer interactions, or other presentations according to the available tools. It is very possible; the teacher uses analogies and metaphors in solving physics problems. In essence, the use of multi-representation must be aimed at making teaching material learned more easily understood, more precise (makes sense), and more useful. In this context, teacher should increase their knowledge concerning the pedagogical content knowledge (Mishra & Koehler, 2006). Tan et al. (2020) asserted that a deeper understanding of a concept is achieved when students apply it in a different situation, describe or define it in their own words, make a model of it, or find an appropriate metaphor for it.

Sixth, involve students in collaborative learning. It is believed by many education experts that collaborative problem solving in small groups will enable solutions, conceptual changes, and transfer of learning to a broader learning context (Mattatall & Power, 2014). Furthermore, Anthony et al. (2018) emphasized that collaborative learning could increase learning motivation and enhance critical thinking skills as well.

Seventh, develop student creativity. According to Morten & Vanessa (2007), creativity is a very important factor for success in school science and every teaching subject matters should be used to cultivate creativity. Through solving the problems that are conducted and applying the transfer of learning will enable students to be able to produce something "new" and will "work" in accordance with the demands of life and desires (Jeffrey & Craft, 2010).

2. Physics Achievement Test (PAT)

a. Analysis of PAT Pre-test and Post-test Mean Scores

PAT Pre-test mean scores between the Transfer of Learning Group (M=27.11, SD= 9.21) and Non-Transfer of Learning Group (M = 27.64, SD = 7.70) were analysed using two-tailed independent samples t-test. Results showed that the groups were significantly undifferent prior to the intervention [t(266) = 0.25, sig (p) = 0.801. The PAT post-test mean scores of the two groups after the intervention were compared using independent samples *t*-test. Results showed that the Transfer of Learning Group (M=64.46, SD = 14.20) and the Non-Transfer of Learning Group (M=52.30, SD=8.06) did differ significantly in the competency of problem solving test [t(246)= 4.19, sig (p) = 0.000] (Table 5).

Table 5
Comparison of PAT posttest means scores

	N	Mean	SD	SE	df	*t*	sig
Transfer of Learning-Model	125	64.46	14.20	2.84	246	4.19	.000*
Conventional Model	123	52.30	8.06	1.40			

$*p < .01$

b. Analysis of PAT Post-test Mean Scores per Topic

Results of independent samples *t*-test showed that the post-test mean scores of the groups after the three times interventions for two topics e.g level of sound intensity and Doppler effect were significantly different, while for sound intensity topic was not significantly different (Table 6).

Table 6
Comparison of PAT post-test mean scores per sound wave topic

Model	Transfer of Learning-			Conventional Model				
Sound Topics	Ideal Mean	Mean	SD	Mean	SD	df	*t*	sig
Sound Intensity	10	8.14	1.86	8.16	2.19	246	0.21	.832
Level of Sound Intensity	40	26.13	2.82	20.04	3.42	246	3.07	.001*
Doppler Effect	50	30.38	1.57	24.10	1.94	246	4.12	.000*

*p < .01

c. The Effectiveness of the Model

Effect Size (ES) analysis for the two dependent variables e.g MPT and PAT by using Cohen's formula showed that the extent of effectiveness of metacognitive strategy-transfer of learning model in increasing prerequisite mathematics knowledge understanding is in high category (ES= 0.86) and problem solving competency in physics is also in high category (ES= 0.83)

This study concluded that the transfer of mathematics knowledge-model could increase the the students' competency in solving problems of physics. This research finding is compliance with many previous studies. Çalışkan et al. (2010) as cited Ince (2018) concluded that applying a problem-solving strategy can develop self-efficacy of first-year undergraduate students as well as foster a positive attitude towards physics. Gök (2006) also concluded that the use cooperative problem solving strategies in physics could enhance the high school students' competencies, learning motivation, and the attitudes regardless gender and initial achievement. Hou et al. (2009) as cited Ince (2018) found that intervention of the problem-solving model 'Online Knowledge-Sharing Discussion could increase the competency of the high school students in solving problems of the mechanics topic. The use of Strategic Video Games followed by Self-Reported Problem-Solving Activities showed significant improvement of learning outcomes and could make students feel more comfortable in learning the fluids topic (Adachi et al., 2013).

Malone (2014) as cited Ince (2018) applied the quasy-experimental control group design to examined the effect of "A Cognitive Awareness Strategies Model" on the physics problem solving skills of high school students. This study concluded that the experimental group students were more competent of applying metacognitive awareness skills than the control. In addition, the ability to solve problems of the experimental group is higher than the control that shows the same characteristics with novice problem solvers. Kohl et al. (2006) examined the influence of mathematical, pictorial, graphical and expressive presentations on the skills to solve physics problems. In their investigations which applied the experimental method with homework, it was concluded that students felt easier to solve physics problems as the mathematical reprentations are trained gradually and explicitly in the teaching-learning process. The research of De Leone and Gire (2005) as cited Ince (2018) also concluded that the ability to solve physics problems of 39 students who use mathematical expressions are more appropriate and better than students who do not use them. It is recommended that to improve the mastery of mathematical knowledge can be done by explicitly training students in the presentation and interpretation of mathematics in the steps of solving physical problems.

According to Costa (1985), the process of thinking process involves cognition and metacognition Many scientists declared that cognitive (thinking) strategies are different from metacognitive strategies (Flavell, 1987; Livington, 1997) and often difficult to distinguish the terms (Seraphin et al., 2012). Debate about what metacognition is often found in many literature. Cognitive and metacognitive strategies may overlap. The same strategy can be considered cognitive or metacognitive depending on what the goals of using that strategy are. For instance, maybe sometimes someone reads something slowly just to learn its contents (cognitive strategies). But, at other times he reads quickly and feels difficulty or ease to get ideas and learn the content contained in the text (metacognitive strategies).

Glynn & Muth (1994) asserted that metacognition is thinking about your thinking as you are thinking to improve your thinking. According to Flavell (1979) as cited in Mahdavi (2014), metacognitive knowledge refers to one's knowledge or beliefs about person variables, tasks, and strategies. Moreover, metacognitive strategy consists of 3 (three) basic processes e.g.planning, monitoring, and evaluating the thinking process to achieve a certain goal (Glynn & Muth, 1994). Several researchers showed evidences that metacognition can be taught and modified (Flavell, 1987; ; Schraw et al., 2006; Djudin, 2020). According to Ertmer and Newby (1996), novice learners; (1) do not check their understanding of the material; (2) do not evaluate the quality of their work; (3) do not make revisions, and are satisfied with just scratching the surface; (4) do not try to examine the problem in depth; and (5) do not make connections or see the relevance of material in their lives. Conversely, expert students are more aware than the novice when they need to evaluate the mistakes (why they fail to understand), monitor the strategies, and redirect their objectives.

Schraw et al. (2006) has examined the instructional intervention of thinking strategies. They concluded that the model could improve the reading comprehension of 171 third and fifth grade students. Simpson and Nist (2000) recommended that instructors need to give explicit instructions about the use of metacognitive strategies in learning. According to Mitchell (2015), the teacher should model " a wrapper strategy"by delivering a brief intervention (giving some tips or hints) related to existing classroom activities to improve students' thinking skills and increase learning, performances as well.

According to the results of previous researches, the problem solving strategies in physics could: (1) change students' misconceptions (Hwang et al., 2014); (2) enhance students' interest, attitude, and motivation (Schraw et al., 2001)**;** (3) enable students feel more confident and joyful in learning (Adachi & Willoughby, 2013; Shute et al., 2016); (4) improve self-regulated learning (Ertmer & Newby, 1996); (5) prepare a more strategic, more reflective, and more independence learner ((Djudin, 2018); (6) improve the tranferring skills of mathematics knowledges (Kereh et al., 2014; Körhasan & Özcan, 2015; Robello et al., 2015); (7) create a meaningful learning (Halloun,1996); (8) link the problems they have learned to daily enterprises (Doktor et al., 2015); and (9) anticipate the requirements of future life (Abromitis,2009; Kwok, 2018).

So, why did the students in the transfer of mathematics knowledge classrooms better than conventional group classrooms in achieving the competency of problem solving of the two topics? Beside the results of several previous studies as summarized above, the conclusion is also supported by the students' actual responses. During periode of the treatment in this study, most of students in the experimental group claimed that using the transfer of mathematics knowledge approach was more understandable. In applying the model, students are trained to use thinking strategies intentionally by the lecturer. They are explicitly trained to apply, compute, and interpret physics concepts using mathematics concepts, and vice versa. Moreover, they were also engaged to gauge the strategies and check the final solution.The students seemed more confidence, more strategic, and more independent. Independence enables students realize that they are attaining their own intellectual needs and acquiring their own information (Abromitis, 2009). Because learning how to learn, developing thinking processes to solve problems is the main goal of education, then metacognitive strategies will be an important element for successful learning.

Finally, critics toward transfer of learning of mathematics knowledge approach should also realize that there is a need for a thorough understanding of its implementation including the variations in individual, group learning space, and some factors that can interfere the internal validity of an experimental design. In fact, the conducive learning environment is assumed to be a means for differentiated instruction that can provide to the varied learning styles of students.

CONCLUSION

The extent of effectiveness of metacognitive strategy-transfer of learning model in increasing prerequisite mathematics knowledge understanding is in high category (ES= 0.86) and problem-solving competency in physics is also in high category (ES = 0.83). The mathematics prior knowledge is a significant pedictor of competency of problem solving. This study not only test the applicability of problem-solving strategies in phyiscs classroom, but also provide a clear insight for problem solving in science education. The instructional intervention of the problem solving model is compliance with the educational investment regarding preparing a qualified prospective teachers. For future study, it is recommended to examine the effect of the model in other topics of physics by analysing the difference of the students' understanding of mathematics knowledge and the effect of teacher subject-matter content knowledge as a covariate variable as well.

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REFERENCES

Abromitis, B. (2009). *Metacognitive strategies for K-12 students: Teaching Students to be Strategic in Thinking will Improve Learning*. Retrieved July 4, 2017, from http://

teaching-Strategies-mentorship. Suite 101.com/article.cfm/Metacognitive Strategies for k-12 Students#xzzOf7wEC6yB.

Adachi, P. J., & Willoughby, T. (2013). More than just fun and games: the longitudinal relationships between strategic video games, self-reported problem solving skills, and academic grades.*Journal of Youth and Adolescence*, 42(7), 1041-1052. https://pubmed.ncbi.nlm.nih.gov/23344653/

Alii, M., Talib, C. A., Ibrahim, N. H., Surif, J., & Abdullah, A. H. (2016). The importance of monitoring skills in physics problem solving. *European Journal of Education Studies, 1*(3), 1-10. https://doi.org/10.5281/zenodo.51089

Anthony, L.B, Nwanekezi, A.U., & William,C (2018). Incorporating collaborative learning strategy as part of an integrated approach in teaching physics in secondary schools. *International Journal of Education, Learning and Development, 6(5),*73-81.

Butler, L., & Coleoni, E. (2016). Solving problems to learn concepts, how does it happen? A case for buoyancy. *Physical Review Physics Education Research, 12(*2), 120-144. https://journals.aps.org/prper/abstract/10.1103/PhysRevPhysEducRes.12.020144

Creswell, J.W. (2008). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research* (3rd ed*)*. Boston: Pearson Prentice Hall.

Costa, A.L. (1985). *Developing Minds. A Resource Book for Teaching Thinking.* Alexandria, Virginia: Association for Supervision and Curriculum Development.

Djudin, T. (2017). Using metacognitive strategies to improve students' ability to comprehend the text and to solve word problems in physics. *Jurnal of Teaching and Learning, 4*(2), 36- 47. https://edulearn.intelektual.org/index.php/EduLearn/article/view/7208

Djudin, T. (2018). Preparing a strategic learner by using metacognitive strategies: From theory into practice. *Journal of Education and Learning (EduLearn), 12*(3), 501-509. https://edulearn.intelektual.org/index.php/EduLearn/article/view/7208

Djudin, T. (2020). An Easy Way to Solve Problems of Physics by Using Metacognitive Strategies: A Quasy-Experimental Study on Prospective Teachers in Tanjungpura University-Indonesia. *Journal of Teaching and Teacher Education an Interntional Journal, University of Bahrain ,8 (1),* 19-27. http: dx.doi.org/10.12785/jtte/080103.

Docktor, J. L., Strand, N. L., Mestre, J. P., & Ross, B. H. (2015). Conceptual problem solving in High School Physics. *Physical Review Special Topics—Physics Education Research*, 11, 1-13. https://doi.org/10.1103/PhysRevSTPER.11.020106

Dorgu, T.E. (2015). Different teaching methods: A panacea for effective curriculum implementation in the classroom*. International Journal of Secondary Education, 3*(6), 77-87. https://www.semanticscholar.org/paper/Different-Teaching-Methods%3A-A-Panacea-for-Effective-Dorgu/dc58952372c7724070d26fa83625baaf0a328c9f

Ellis, A.K., & Bond, J.B. (2014). An analysis of research on metacognitive teaching strategies. *Prodia-Social and Behavioral Sciences*, *32*(116), 4015-4024.

https://www.studentachievement.org/wp-content/uploads/Metacognitive-strategies-lit-review-1-s2.0-S1877042814009008-main.pdf

Ertmer, P.A. & Newby, T.J. (1996). The Expert learner : Strategic, self-regulated, and reflective. *Instructional Science,* 24 (1), 1-24. http://allianceforlearning.co.uk/wp-content/uploads/2017/03/

Ewies, M.G., Ahmad, A. C., & Hamzah, A. (2021). The availability of problem-solving skills among gifted students in schools of excellence and its relation with their parents' academic level. *International Journal of Instruction*, 14(3), 705-716. https://doi.org/10.29333/iji.2021.14341a

Fadel, C., Trilling, B., & Maya, B.M. (2016). Metacognitive strategies are powerful tools for any discipline, interdiscipline or for Learning in general**.** Retrieved July 14, 2017, from https://ww2.kqed.org/-mindshift/2016/08/10/the-role-of-metacognition-in-learning-and-achievement/

Flavell, J.H. (1987). Speculations about the Nature and Definition of Metacognition (in Reinert & Kluwe (eds). *Metacognition, Motivation, and Understanding* (pp.136-140). New Jersey: Lawrence Erlbaum Associates Publishers.

Gentner, D., Loewenstein, J., & Thompson, L. (2003). Learning and transfer: A general role for analogical encoding. *Journal of Educational Psychology*, *95*(2), 393-405. https://psycnet.apa.org/record/2003-00780-016

Glynn, S.M., & Muth, K.D. (1994). Reading and writing to learn science: Achieving scientific literacy. *Journal of Research In Science Teaching*, *29*(6), 35-49. https://onlinelibrary.wiley.com/doi/10.1002/tea.3660310915

Greiff, S., Wüstenberg, S., Molnár, G., Fischer, A., Funke, J., & Csapó, B. (2013). Complex problem solving in educational contexts—Something beyond: Concept, assessment, measurement invariance, and construct validity. *Journal of Educational Psychology*, 105(2), 364–379. https://doi. org/10.1037/a0031856

Gunawan, G., Suranti,N.M.Y., Nisrina, N., & Herayanti. L. (2018). Students’ problem-solving skills in physics teaching with virtual labs. *International Journal of Pedagogy and Teacher Education*, *2*,79-89. DOI: 10.20961/ijpte.v2i0.24952

Halim, A., Yusrizal, Y., Susanna, S., & Tarmizi, T. (2016). An analysis of students’ skill in applying the problem-solving strategy to the physics problem settlement in facing AEC as global competition. *Journal Pendidikan IPA Indonesia, 5*(1), 1-5. https://www.researchgate.net/publication/307850228

Halloun, I. (1996). *Schematic modeling for meaningful learning of physics, Journal of Research In Science Teaching*, *33*(9),1019-1019. https://www.researchgate.net/publication/242537147

Hollabaugh,M.(2017). *Physics problem solving strategy.* http://www.nr.cc.mn.us/physics/Faculty/HOLLABGH/probsolv.htm

Hou, H. T., Sung, Y. T., & Chang, K. E. (2009). Exploring the behavioral patterns of an online knowledge-sharing discussion activity among teachers with problem-solving strategy.*Teaching and Teacher Education*, *25*(1), 101-108. https://www.sciencedirect.com/science/article/abs/pii/S0742051X08001212

Hwang, G. J., Kuo, F. R., Chen, N. S., & Ho, H. J. (2014). Effects of an integrated concept mapping and web-based problem-solving approach on students' learning achievements. perceptions and cognitive loads. *Computers & Education*,*71*,77-86. https://www.sciencedirect.com/science/article/abs/pii/S0360131513002686

Ince, E. (2018). An overview of problem-solving studies in physics education. *Journal of Education and Learning*, *7* (4), 191-200. https://eric.ed.gov/?id=EJ1179603

Jeffrey, B., & Craft, A. (2010). Teaching creatively and teaching for creativity: Distinctions and relationships. *Educational Studies*, *30*(1), 77-87. doi:10.1080/0305569032000159750

Kereluik, K., Mishra, P., Fahnoe, C., Terry, L., & Karr, J. A. (2013). What knowledge is of most worth: teacher knowledge for 21st century learning. *Journal of Digital Learning in Teacher Education*, 29(4), 127. https://doi.org/10.1080/21532974.2013.10 784716

Kereh, C.T. (2014). Korelasi penguasaan materi matematika dasar dengan penguasaan materi pendahuluan fisika inti. *Jurnal Pendidikan Fisika Indonesia*, *10*(2),89-97. DOI: 10.15294/jpfi.v10i2.3350

Kretzschmar, A., & Süß, H. (2015). A study on the training of complex problem-solving competence. *Journal of Dynamic Decision Making*, 1(4), 1–14. https://doi.org/10.11588/ jddm.2015.1.15455

Koch, A. (2001). Training in metacognition and comprehension of physics texts, *Science Education*, 85, 758-768. https://onlinelibrary.wiley.com/doi/10.1002/sce.1037

Kohl, P. B., Rosengrant, D., & Finkelstein, N. D. (2006). Comparing explicit and implicit teaching of multiple representation use in physics problem solving. *Physics Education Research Conference, 883*, 145-148. https://doi.org/10.1063/1.2508713

Körhasan, N. D., & Özcan, Ö. (2015). Examination of the variation in students' problem-solving approaches due to the use of mathematical models in Doppler Effect. *Hacettepe University Journal of Education*, *30*(3), 87-101. https://core.ac.uk/display/286727161

Kwok. S.(2018). Science education in the 21st century. *Journal of Nature Astronomy*, 2. 530-533. DOI:10.1038/s41550-018-0510-4.

Livingston, J.A. (1997). Metacognition: An Overview. Retrieved July 4, 2017, http://gse.buffalo.edu/fas/shuell/CEP564/Metcog.htm

Macaulay, C.& Cree, V.E. (1999). Transfer of learning: Concept and process. Journal Social Work. The International Journal, 18(2), 183-194.

Magaji, A.(2021). Promoting Problem-Solving Skills among Secondary Science Students through Problem Based Learning. *International Journal of Instruction,* 14(4), 549-566. https://www.e-iji.net/dosyalar/iji_2021_4_32.pdf

Mahdavi, M. (2014). An Overview: Metacognition in education. *International Journal of Multidisciplinary and Current Research*, *2*(14), 529-535. http://ijmcr.com/wp-content/uploads/2014/05/Paper5529-535.pdf

Mattatall, C & Power, K. (2014). *Teacher collaboration and achievement of students with LDs: A Review of the Research.* Avalable: http://ldatschool.ca/literacy/the-impact-ofteacher-collaboration-on-academic-achievement-and-social-development-for-studentwith-learning-disabilities-a-review-of-the-research/

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054. http://one2oneheights.pbworks.com

Mitchell, M.P. (2015). *Metacognition: Nurturing Self-Awareness in the Classroom*. https://www.edutopia.org/blog/8

Morten,P. & Vanessa, K. (2007). *Creativity in Science Education: Perspectives and Challenges for Developing School Science*. http://www.redorbit.com/news/science/915320/

National Research Council. (2000). *Inquiry and the National Science Education Standards: A guide for teaching and learning.* Washington D. C.: National Academy Press. http://www.nap.edu/openbook.php?record_ id=9596&page=25

Obafemi & Ogunkunle. (2013). Mathematics abilities of physics students: Implication for the application and analysis of sound waves**.** *Journal of Education and Practice*, *4*(24), 102-110. http://www.sapub.org/journal/authorguidelines.aspx?journalid=1070

Olaniyan, O., & Omosewo, E. O. (2015). Effects of a target-task problem-solving model on senior secondary school students' performance in physics. *Science Education International*, 25(4), 522-538. https://www.theijes.com/papers/vol7-issue7/Version-2/C0707021724.pdf

Reddy, M.V.B. & Panacharoensawad, B. (2017). Students problem-solving difficulties and implictions in Physics: An empirical study on influencing factors. *Journal of Education and Practice*, *8* (14),59-62. https://eric.ed.gov/?ti=Change+Strategies

Robello,N.S., Cui,L., Bennett, A.G.,Zollman ,D.A.,& Ozimek, D.J. (2015). *Transfer of learning in problem solving in the context of mathematics and physics*. https://TransferInProblemSolving-FullChapter-v32.pdf

Saavedra. A. & Opfer. V. (2012). *Teaching and learning 21th century skills*: *Lessons from the learning sciences*. New York. Asia Society: A Global Cities Education Network Report.

Salame, I.I, Ramirez, L., Nikolic, D., & Krauss, D. (2022). Investigating Students' Difficulties and Approaches to Solving Buffer Related Problems. *International Journal of Instruction,* 15(1), 911-926. https://doi.org/10.29333/iji.2022.15152a.

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning, *Research in Science Education, 36*(2), 111-139.

Sharma, A. (2013). Transfer of learning: Types and theories of transfer of Learning. https://www.psychologydiscussion.net/essays/594

Seraphin et al. (2012). Metacognition as a means to increase the effectiveness of inquiry-based science education. *Science Education International, 23*(4), 366-382. https://eric.ed.gov/?id=EJ1001630

Shute, V. J., Wang, L., Greiff, S., Zhao, W., & Moore, G. (2016). Measuring problem solving skills via stealth assessment in an engaging video game. *Computers in Human Behavior, 63*, 106-117. https://orbilu.uni.lu/handle/10993/27999

Simons, P.R.J. (1999). Transfer of learning: Paradoxes for learners, *International Journal of Educational Research, 31* (7), 577-589. doi:10.1016/S0883-0355(99)00025-7

Stenger, M. (2017). 10 Ways to improve transfer of learning. https://www.opencolleges.edu.au/informed/features/10-ways-improve-transfer-learning/

Taale, K.D. (2011). Improving physics problem solving skills of students of Somanya Senior High Secondary Technical School in the Yilo Krobo District of Eastern Region of Ghana. *Journal of Education and Practice, 2,* 8-15. https://doi=10.1.1.845.2675&rep=rep1&type=pdf

Tan, R.M., Yangco, R.T.& Que, E.N. (2020). Students' conceptual understanding and science process skills in an inquiry-based flipped classroom environment. *Malaysian Journal of Learning & Instruction*, *17* (1), 159-184. https://www.semanticscholar.org/7161b2a6e1fc350d2e803e897773d2a4aecbe938

The Ohio Academy of Science. (2007). *The Ohio core curriculum: What's required for science*. Retrieved from http://www. ohiosci.org.

Walker, J. (2008). Halliday and Resnick Fundamental of Physics Extended Eight edition. New Jersey: John Wiley and Sons (Asia) Pte Ltd.

Yakupoglu, F. (2012). The effects of cognitive and metacognitive strategy training on the reading performance of Turkish students.*Practice and Theory in Systems of Education*, *7*(3),353-358. http://eduscience.fw.hu/2113FilizYakupoglu.pdf

Zohar, A. & Barizilai,S. (2013). A review of research on metacognition in science education: Current and future directions. *Studies in Science Education,.49*, 121-169. https://www.tandfonline.com/doi/abs/10.1080/03057267.2013.847261