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Mean-End Analysis: A Revised Polya Strategy for Enhancing the Students' Competency in Solving the Effect Doppler Problems of Physics

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ABSTRACT: The main objective of this research is to examine the level of effectiveness of implementing the Means-End Analysis (MEA) in improving the senior high school students' ability to solve problems on Doppler Effect of Physics and its impact on the retention. A Quasy-Experiment method with a one group immediate post-delayed test design was applied in this study. The target population was the eleventh grade of public senior high school students in West Kalimantan Province with the characteristics of not having studied the Doppler Effect material. The research sample was taken using a multistage random sampling technique. Nine schools were selected consisting of nine intack classes amount of 260 students. Amount of four items of essay learning outcomes test was administered in this study. Based on the data analysis, it was concluded that the application of Means-End Analysis (MEA) strategy was effective in enhanching students' ability to solve questions on the topic of the Doppler Effect and its impact on students' memory (retention). It is recommended to teachers that learning to solve problems using the Doppler effect material needs to use audio-visual media, for example; PhET simulations, or virtual laboratories.

KEYWORDS : Problem solving, Mean-End Analysis, Expert versus Novice, Memory-Retention, Effectiveness

INTRODUCTION

Some skills that must be possessed in the 21st century include critical thinking, problem solving, information literacy, and global awareness (Rotherham & Willingham, 2009). Therefore, today's educational policies, almost all over the world, aim to improve students' problem-solving abilities and skills. Problem solving is considered one of the universal skills, needs and requirements of the 21st century (Gok, 2010; Ibrahim & Rabello, 2012; Octor et al, 2015). Physics is believed to have the potential to develop problem-solving skills (Ince, 2018). The ability to solve physics problems (questions) is largely determined by mastery of concepts and principles, language skills, thinking strategies and mathematics skills (Walker, 2008). It is explained that to be able to solve physics problems, students must know and understand the concepts and principles (formulas, laws and principles) of physics and have problem solving strategies that can be applied to the new situation to be solved (Hou, et al., 2009).

Problem solving ability can be interpreted as the skill of applying previously acquired knowledge to new or unknown situations, to find solutions to the problems faced using all the knowledge possessed (Arends, 2012). In Indonesia *Kurikulum Merdeka*, it is hoped that increasing students' abilities and problem-solving skills can be developed in the independent learning policy. Teachers are required to be able to innovate learning methods/strategies to improve various student competencies, for example; high-level thinking (HOT), problem solving, scientific literacy, and numerical literacy are in accordance with learning styles and characteristics of teaching materials and relate to the context of everyday life (Yandri, 2022).

Unfortunately, the problem-solving abilities and skills of high school students, in particular, in physics lessons in Indonesia (Pardimin & Widodo, 2017; Safitri et al., 2017; Fathiah & Utari, 2015; Sekarpratiwi et al., 2018) and in many foreign countries country (Gok & Silay, 2010; Hong et al., 2012; Ekici, 2016; Ince, 2018) is currently considered to be relatively low. From exploring several research results and teaching experience, it can be concluded that several factors cause difficulties experienced by students in solving physics questions, including: major obstacles focused on the inability to fully understand the questions, concepts and principles, not able to apply initial knowledge and mathematical skills (algebra, trigonometry, calculus), and does not have thinking strategies that are appropriate to the problem at hand (Reddy & Panacharoensawad, 2017; Adianto & Rusli, 2021; Dewi Sartika & Nur Aisyah, 2018; Reddy, 2017; Hong et al.; 2012

Therefore, several of current research that aims to improve physics problem solving abilities and explore the causal factors recommends the need for learning interventions, for example; apply problem solving strategies that are appropriate to the characteristics of the teaching material (Dorgu, 2015; Ince, 2018). Hollabaugh (2013) explains that there are 2 (two) factors that can help to become a good physics problem solver. *First*, you must know and understand the principles of physics. *Second*, there must be a strategy or learning model for applying these principles to new situations especially in daily life where physics can help.

Mean-End Analysis: **A Revised Polya Strategy** for **Enhancing** the **Students' Competency** in **Solving** the **Effect Doppler Problems** of **Physics**

One of the physics topics related to daily life is Doppler Effect. In learning this topic, the students asked to calculate the frequency of the sound source (ambulance siren or motor vehicle horn) heard by the observer (listener). However, at huge amount of schools this topic is often considered difficult by many students. This difficulty causes many mistakes that students make when working on Dopper Effect questions. Some of the mistakes that stand out include; (1) students cannot write new formulas that are correct according to the problem situation they are facing; (2) students incorrectly write the sign (+) or (-) for the speed of the sound source or observer; and (3) students are wrong in carrying out calculations to determine the final solution. Apart from that, the structure of the questions on the Doppler Effect topic, in general, is in the form of ill-structured problems (Lupita, 2019). These learning difficulties and errors need to be sought for alternative solutions by teachers. One of them is by explicitly and systematically applying and modeling innovative problem solving strategies by using Means-End Analysis (MEA).

In solving Doppler Effect problems, the problem solving strategy commonly used by teachers is the Polya strategy which is considered a powerful problem solving strategy in physics education (Yeoh, et al., 2012). The main steps in solving the problem are; (1) Understand the problem (Understand the problem); (2) Create a settlement plan (Devise a plan); (3) Implement the plan (Carry out the plan); (4) Rechecking the solution obtained (Look back) (Polya, 1945). In contrast to Polya stategy, Means-End Analysis (MEA) is a problem solving strategy where the final goal is identified first (*End*) and then completed through the *analysis* (creation) of several sub-goals (subgoals) and action plans (*means*) that help achieving that final goal. The MEA problem solving process can be achieved through three stages. *First,* goal transformation by trying to simplify the current state (current statement) obtained from new information resulting from problem solving and the goal to be achieved (goal state). *Second*, reduction of goals, namely forming sub-goals "these methods form a recursive system that generates a tree of subgoals in attempting to attain a given goal". *Third*, apply operators to achieve goals (Payne, 2024),

In the MEA strategy, to achieve the final goal of the question (*End*), the teacher encourages students to make plans and analyze (*Analysis*) or methods/strategies (*Means*) by writing down several subgoals. It is hoped that students' creativity and independence in analyzing several subgoals can be developed. The agreement on marking (+) or (-) on the speed of the sound source and the observer is analyzed using the concept of fractions (mathematics), namely the relationship between the numerator and the denominator. Thus, students' own discovery of a new formula for the Doppler Effect that is appropriate to the problem they are facing is expected to be more meaningful.

From tracing study, it is found that some previous investigations have been conducted that tested the effectiveness of implementing the Means-End Analysis strategy and Polya in physics learning. Aras's (2020) research concluded that the MEA strategy is effective for developing problem solving and productive disposition abilities in mathematics lessons. Juniyarti Class Action Research (2014) concluded that students' analytical skills could improve from cycle I to cycle II by 80.93% and were categorized as good. Research by Permatasari et al. (2019) concluded that there was an influence of implementing the MEA strategy on the physics problem solving abilities of class XI students at SMA Negeri 4 Sidoarjo. Research by Indahwati et al. (2017) concluded that the application of the MEA strategy had a significant influence on students' critical thinking abilities. Maries, & Singh (2023) emphasized that the application of problem solving strategies (including Polya and MEA) in physics education can improve 3 (three) categories of student abilities, namely; knowledge organization, information processing and cognitive load, and metacognition

From the results of searches in several journals, both domestic and foreign, previous research that tested the effectiveness of applying the Means-End Analysis on the ability to solve questions on the topic of the Doppler Effect and its impact on memory (retention) has not been much, perhaps never, carried out. Furthermore, several factors regarding students' difficulties in solving physics problems are the main concerns in this research. Therefore, the involvement of public high school teachers and students in learning innovative problem solving strategies in large numbers (representative) in West Kalimantan is quite rational to investigate.

The focus of problem of this study is to what extent is the level of effectiveness of implementing the Means-End Analysis (MEA) in improving the ability to solve problems on Doppler Effect material and its impact on the memory (retention) of eleventh grade students of public senior schools in West Kalimantan?

METHOD

This research applies the Quasy-Experiment method with a one group post-delayed test design (Borg & Gall, 2008; Creswell, 2013) to test the effectiveness of physics learning using the Means-End Analysis strategy as an effort to improve high school students' ability to solve Doppler Effect problems. in the even semester of the 2023/2024 academic year. The resesearch design was implemented with the consideration that the Doppler Effect material and MEA strategy were considered to have never been studied and introduced by teachers before. Of course, in this initial condition, students have no prior knowledge and were convinced not able to solve Doppler Effect problems well. The delayed test was administered to asses the level of retention.

The target population was the 533 eleventh grade of public senior high school students in West Kalimantan with the characteristics of not having studied the Doppler Effect material. The research sample was taken using a multistage random sampling technique. *First*, to determine the sample of schools in terms of their location (in the provincial capital, district/city capital, and sub-district capital), a stratified cluster random sampling technique was used. A total of 9 public senior high schools in the West Kalimantan

Province region were selected. *Second*, after the nine schools were selected, the intack group random sampling technique was used. The research sample consisted of 260 students.

The nine teachers-- as co-researchers--involved voluntarily in this research were high school physics teachers who taught Doppler Effect material in the second semester of the 2023/2024 academic year. They have been given short training first regarding problem solving learning practices using the Means-End Analysis strategy at the Physics Learning Laboratory of FKIP Untan from February 2-3, 2024. The training contains an understanding of the scientific concepts of the Doppler Effect. The operational exemplars of general guideline for the steps or syntaxes of the MEA strategies is described below.

Problem:

A police car chases a speeding Porsche 911. Assume the maximum speed of the Porsche is 80.0 m/s and the maximum speed of the police car is 54.0 m/s. At this time both cars reach their maximum speed. What frequency does the Porsche driver hear if the police car's siren frequency is 440 Hz? For example, the speed of sound in air is 340 m/s. (Answer: 400 Hz, taken from: Walker, Physics University)

Step 1*; **Means or Strategies**:*

- Write down what is asked or the final goal of completion (*End*)
- What frequencies does the Porsche driver hear

Describe (*End*), whether the Doppler effect occurs and relationship between frequency of observer f_p (*pendengar*) and frequency of source f_s (*sumber bunyi*)

- Understand the problem: The police (with their sirens) chased the driver of the Porsche. The speed of the police car is 54 m/s chasing the driver at 80 m/s.

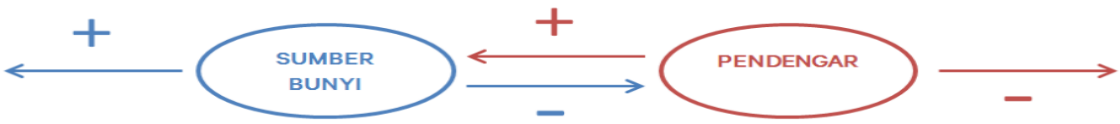
It means that the sound source approaches the listener and the listener moves away from the source: (Doppler effect occurs, and f_p < f_s)

- So, we will get a value of k <1, because the value of the numerator must be smaller than the value of the denominator of the fraction.)

***Step 2**, **Means or Strategies**:*

- Do some analysis of the sub-goals (Means or Subgoals)

Subgoal 1: Make a chart or sketch or free-body diagram, as below:



- Subgoal 2: Determine the positive (+) or negative (-) sign for the source speed (vs)
- v_s = (-) 54 m/s : the sound source is a police car siren (source approaches listener)
- v_p = (-) 80 m/s: the driver of the Porsche moves away from the police car (listener moves away from source)
- Subgoal 3***:*** Contruct a new formula:

$$f_p = \frac{(v - v_p)}{(v - v_s)}\, f_s$$

- Subgoal 4: Do basic mathematical computation carefully;

$$f_p = \frac{(v - v_p)}{(v - v_s)}\, f_s$$

$$f_p = \frac{(340 - 80)}{(340 - 54)}\, 440\ Hz$$

$f_p = 386{,}49 \cong 400\ Hz$ (sesuai kunci)

***Step 3**: **Means or Strategies**:*

- Recheck the final solution (*End*) obtained
- Recheck the algorithms and mathematical calculations that have been carried out
- The results obtained above, namely f_p= 400 Hz are smaller than f_s= 440 Hz.
- ***Conclusion***; Therefore, it makes sense or correct and is in accordance with End's description in step 1.

The timeline of this study regarding treatments, the learning subject matters, the immediate posttest, and d*elayed Posttest*) were described in Table 1 as follows.

Table 1: Timeline of Research

Treatment	Subject Matter for MEA Classes
Pretest	-
Treatment-1	Type 1 Problem: One of the sound sources or the listener is silent (not moving)
Treatment-2	Type 2 Problem: The source of the sound and the listener are approaching or moving away from each other
Treatment-3	Type 3 Problem: The source of the sound and the listener approach each other and pass each other
Immediate Posttest	Learning outcome test of Doppler Effect
Delayed Posttest *(one month after immediate posttest)*	Learning outcome test of Doppler Effect

There are 2 (two) main instruments in this research, namely the scenario or lesson plan for 3 (three) treatments and an 4 items essay learning outcomes test with allocated time for processing. 60 minutes. After the final test, students are asked not to discuss solving test questions, individually or in groups. The lesson plans and research test questions have been validated qualitatively by teachers in the research sample schools.

Tests of mean differences between immediate posttest and delayed-test scores used parametric statistics independent samples t-test (if the data is normally distributed) or U-Mann Withney (if the data is not normally distributed). The level of effectiveness of problem solving after learning using the Means-End Analysis, scores were analyzed using the effect size (ES) formula from Cohen d. Interpretation of ES Values used the categories,namely: $ES \geq 0.80$: high; $0.20 < ES < 0.80$; moderate, and $ES < 0.20$: low. To measure the level of the effect of the MEA strategy ostudents' retention in solving Doppler Effect problems, data will be analysed by using the formula: Retention (R) = $\frac{\textit{Mean of delayed test}}{\textit{Mean of immediate posttest}}$ X 100%

Interpretation of retention (R) used the categories,namely: $R \geq 70$ %: high; $60\% < R < 70\%$; moderate, and $R < 60\%$: low.

RESULT AND DISCUSSION

The data collected is numerical data (scores) obtained from the immediate posttest and delayed test. Students who did not take the two tests were not included in data analysis.

1. Result of Normal Distribution Test

Before data analysis is carried out using parametric or non-parametric statistics, it is necessary to test the normality of the score distribution by using the Kolmogorov-Smirnov test. The assymot significant value of Kolmogorov-Smirnov are consecutively 0.154 for immediate posttest and 0.143 for delayed test. It is concluded that the data distributions are normal.

2. Result of Statistic Descriptives

The average score of students after having involved in learning the Means-End Analysis strategy lies in the range 39.55 – 93.97. Statistic descriptives of immediate posttest and delayed test are listed in Table 2.

Table 2. Statistic descriptives of immediate posttest and delayed test

Statistic Descriptives	Immediate Posttest	Delayed Test
Number of students (n)	260	260
Mean	71.29	60.44
Standard Deviation (SD)	22.63	21.96
Ideal score	100	100
Minimal score	10	5
Maximum score	100	100

3. Result of the mean difference test after treatment

Due to the scores are normally distributed, the mean difference test after treatment between the immediate posttest and delayed test applied the paired-sample t-test. The results is presented in Table 3.

Table 3. Result of the mean difference test after treatment

Test	n	Mean	t-value	Assy. sig	Conclusion
Immediate posttest	260	71.29	3.29	0.001^{*}	Rejected Ho
Delayed test	260	64.87			

** Significant at $p < 0.05$*

From Table-3, it can be seen that the results of the mean difference test, t-value = 3.299 ($p < 0.05$), which means that it rejects Ho. This means that there is a significant difference in problem solving abilities after having learning the Means-End Analysis of the Doppler Effect material between the immediate posttest and delayed test.

4. Result of *Effect-Size* (ES)

The level of effectiveness of problem solving strategy of Means-End Analysis, data (scores) were analyzed using the Cohen *d* formula of Effect Size (ES). The result is presented in Table 4.

Table 4. Result of Effect-Size (ES)

Test	n	Mean	ES	Category
Immediate posttest	260	71.29	0.28	Moderate
Delayed test	260	64.87		
Pooled SD	22.46			

From Table 4, it can be seen that the ES value which shows the level of influence of implementing the Means-End Analysis strategy on students' problem solving abilities in the Doppler Effect material is 0.28 (classified in the moderate category).

The findings of this research are in line with several previous studies. Gök (2006), for example, investigated the influence of cooperative problem-solving strategy teaching methods on middle school students' physics success, achievement motivation, and problem-solving attitudes, strategy use, and gender and achievement level. In experimental studies, it was reported that teaching cooperative problem solving strategies had a positive effect on students' physics achievement and attitudes. Hou et al. (2009) concluded that the competence of high school teachers and students in solving mechanical problems increased significantly after receiving the Online Knowledge Sharing Discussion model intervention. Adachi et al. (2013) who used Strategic Video Games followed by a Self-Reported Problem Solving Activity have succeeded in making students felt happier and have had an impact on increasing fluid dynamic abilities.

Costa (1985) states that problem solving for any subject matter content will use a thinking process that involves cognition and metacognition (Costa in Djudin & Amir, 2018). Many previous studies confirm that problem solving abilities are influenced by metacognition, mathematics achievement, attitude, motivation, self-efficacy, and self-confidence (Byu & Lee, 2014; Gök, 2014; Docktor el al., 2015). According to Mahdavi (2014), metacognitive knowledge refers to a person's knowledge or beliefs about person, task, and strategy variables. This metacognitive knowledge can be modified or revised through the use of metacognitive strategies. Glynn and Muth (1994) identified that metacognitive strategies consist of the process of planning, monitoring, and evaluating our thinking to achieve certain goals.

Most researchers showed evidences that metacognitive strategies in problem solving can be taught (Koch, 2001; Mitchell, 2015; Redish, 2004; Schraw et al., 2006). For example, Schraw et al. (2006) found that third and fifth grade students' metacognitive skills could be improved through directed learning modeling. To deepen students' reading comprehension of texts and improve their ability to solve story problems in physics, instructors need to explicitly model the use of metacognitive strategies in their learning (Djudin & Amir, 2018). In learning to read, for example, students must be trained to observe messages separately from their context, and often in search of possible meanings and implications, not just memorize the information they learn (Seraphin et al., 2012). It is stated that metacognitive strategies will be an important element for successful learning (Halloun, 1996; Koch, 2001), and therefore, it is considered a fundamental goal of (physics) education.

Based on several theoretical studies, it can be concluded that using problem solving strategies that are appropriate to the content of physics subject matter can; (1) encourage students' conceptual changes; (2) foster students' situational interest, good attitudes and achievement motivation; (3) make students feel more confident, happy and happy; (4) increase students' self-efficacy and self-regulation; (5) prepare students to become strategic and independent learners; (6) make students become skilled or experienced thinkers; (7) increase students' mathematical knowledge; (8) increase students' ability to interpret the problems they face in daily activities more logically and systematically; and (9) prepare students to become good citizens in anticipating the needs of life in the future.

Students' ability to solve problems in physics material is also influenced by the teacher's experience. In this context, teacher status can be classified into experienced/senior teachers, who are considered expert teachers and inexperienced/junior teachers, who are considered novice teachers. Knowledge of the characteristics of these two teacher statuses has implications for developing and assessing their pedagogical practices. Sohani et al (2018) emphasize that it takes a lot of practical training and years of experience to acquire routine behavior and full automaticity in problem solving that allows further improvements to be made.

Based on a literature review regarding experts and novices in problem solving, several characteristics of experts can be summarized, including: (1) as having a large and well developed knowledge base that enables fast and accurate performance in routine and more complex situations; (2) can apply their knowledge more flexibly when understanding a situation and deciding on their next course

of action; (3) have a coherent knowledge structure that allows direct access to knowledge; (4) have the ability to monitor steps, procedures, carefully; (5) are better able to enhance their learning from experiences by seeking feedback to improve their own performance and investing effort in deliberate practice.
According to Marshall (2022), problem solving abilities can be taught in every teaching material and can be combined with other extra-curricular concepts. There are at least 5 (five) benefits that can be obtained from learning problem solving in education, they are: (1) problem solving is student-centered; (2) problem solving can increase confidence and learning outcomes in all teaching materials; (3) problem solving can encourage cooperation and teamwork; (4) problem solving can improve metacognitive skills; and (5) problem solving can help retain knowledge (memory) over a long period of time.
Creativity Asia (2017) confirmed 7 (seven)reasons why problem solving is important for children's intellectual development. *First*, increase curiosity & self-confidence. People with effective problem-solving abilities become innovative and independent by learning through their experiences. in addition, they build self-confidence because they encourage people to believe in their abilities. *Second*, train them to make better decisions. This helps them make rational decisions and not depend on others. students organize and control their own learning). children can learn to collect and process information independently. *Third*, help students achieve better in academics. This allows them to face the various factors that stand in their way and achieve their academic goals. they are involved in original investigations and develop inquiry skills. *Fourth*, improve the ability to make social connections. This helps them develop healthy relationships because they are able to manage conflict in relationships and build better social skills. Effective problem solving skills also encourage students to work in teams. This increases collaboration and promotes new leaders. *Fifth*, improve critical thinking. Problem solving skills improve cognitive abilities such as attention, focus and memory. In addition, cause and effect are more deeply understood by students who can solve problems effectively. Therefore, critical thinking skills are also improved. *Sixth*, develop patience. Children also develop patience while solving problems effectively thereby helping them in taking calculated risks. *Seventh*, build resilience. Lastly, it helps children adapt to change and build resilience to difficult circumstances.

5. Result of *Retention*

To measure the extent of the effect of the MEA strategy on memory (retention) in solving Doppler Effect problems, the Retention (R) formula is used as explained in the Method section. Delayed test was given within 1 month after treatment. Result of Retention is presented in Table 5.

Table 5. Result of Retention

Test	n	Mean	R-value (%)	Interpretation
Immediate posttest	260	71.29	84.78	High
Delayed test	260	60.44		

From Table 5, it can be seen that the retention value (R) for the Means-End Analysis strategy is 84.78 (classified as high category). In other words, it can be explained that students' memory for applying the Means-End Analysis strategy is relatively high. This is indicated by a decrease in the average score for the ability to complete problem solving questions from 71.29 (on the immediate posttest) to 60.44 (on the delayed test).
This finding is in line with several previous studies that measured retention of treatment, for example; related to the application of memory techniques (mnemonics).Research by Dania et al. (2023) concluded that the Mnempnics method, as a mental anchor tool, was able to improve learning outcomes and students' memory on material on the classification system of living things. Djudin's research (2020) concluded that the application of note-taking techniques in the form of Graphic Postorganizers was able to improve the learning outcomes and memory of students in class 2 of junior high school on Solar System material with a retention rate of 85.12% (classified as high category).
Theoretically, learning retention is a person's ability to transfer new information into their long-term memory so that it is easy for them to recall and put that knowledge to use in the future. In simpler words, learning retention is all about making new knowledge stick for a long time (Azmi, et al.,2016). Students really need the ability to remember in the thinking and learning process. A person's memory can be seen from his ability to store information that has been received and be able to recall it at a later date. This storage process is related to the way information can be received, constructed, and finally stored in the individual's mind (Bakken, 2011). Remembering is a complex collection of electrochemical reactions activated through multiple sensory channels and stored in a highly complex and unique neural network throughout the brain. This dynamic nature of memory continues to change and develop along with the increase in stored information (Scruggs & Mastropieri, 2000)
Remembering is the process of remembering information. Information that has been obtained will be processed in memory through certain stages. So, memory is not something that happens instantly but requires a certain process or strategy to obtain it. Remembering is considered an effective way to transfer information from short-term memory to long-term memory so that in the learning process it is easier to achieve learning goals. According to Ahmadi (2009), the ability to remember in humans means that

there is an indication that humans can store and recreate something they have experienced. However, in general, people easily forget things they have experienced.

Each individual's ability to remember is different. The ability to remember can be improved through the process of taking notes (Arslan, 2002). The ability to remember students depends on the learning method used by the teacher and the practice teachers use with this method to make it effective in the learning process (Bakken, 2011). The mnemonic method is a way of storing information (in the brain) easily and quickly for recall. Mnemonic strategies can build relationships so that the objects studied are not only memorized, but also have conceptual relationships. The method used to improve memory requires the brain's ability to connect words, ideas and fantasies so that it is useful for solving problems which then lead to understanding a concept. Mocko et al. (2017) emphasized that mnemonics are very useful for helping students remember information (recall information) and can reduce stress.

According to Uno & Umar (2014), there are 4 (four) factors that affect learning retention for a student. *First*, interest and motivation. The interest and motivation of a learner behind a learning program are of uppermost importance. When learning is accompanied by a motive, it is often retained for a long time because the human brain tends to focus more on matters of interest. *Second*, repetition. Repetition of the learning material plays an essential role in learning retention. The more an individual repeats or practices a task, the better it is retained in their memory. *Third*, association. Paying attention to the meaning and significance of the content or associating it with real-life scenarios helps individuals learn quickly and retain the information longer. *Fourth*. use of multiple channels. Different people prefer different learning styles – some are visual learners, some need hands-on experience, some require an instructor to guide them, etc. Therefore, it's important to choose the appropriate learning method or technique to boost learning retention for an individual.

CONCLUSION AND SUGGESTION

In line with the research objectives, the conclusion that can be drawn is that the application of Polya and Means-End Analysis (MEA) strategies is effective in enhancing students' ability to solve problems on the topic of the Doppler Effect in moderate category. The level of retention of students' ability to solve problem in the delayed test given at an interval of 1 month after the immediate posttest was classified as high category.

Because of problem solving, in fact, is a dimension of procedural knowledge, explicit, systematic and deliberate modeling by teachers regarding the steps to solve physics problem solving problems needs to be carried out in the classroom learning process. For advanced researchers, the effect or effectiveness of implementing the Means-End Analysis (MEA) strategy on improving problem-solving abilities can be expanded, for example, by involving other influential variables or factors (for example; interest and motivation to learn, learning style, independence learning, self-efficacy, and self-awareness) and the desired use of factorial design using two/three way anova.

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REFERENCES

1) Azmi, M. N. L., Najmi, M. H. S. M., & Rouyan, N. M. (2016). A case study on the effects of mnemonics on english vocabulary. *International Journal of Applied Linguistics & English Literature*, 5(7), 178-185. DOI:10.7575/aiac.ijalel.v.5n.7p.178
2) Adianto , T. & Rusli M.A.(2021). Analysis of Student Difficulties in Solving Physics Problem: Impulse and Momentum Topics. *Unnes Science Education Journal*, 10(1), 1-10. https://journal.unnes.ac.id/sju/index.php/usej/article/view/41517
3) Amiryousefi. (2011). Mnemonic instruction: A way to boost vocabulary learning and recall. *Journal of Language Teaching and Research*, 2(1), 178-182, DOI: 10.4304/jltr.2.1.178-182.
4) Anderson, L.W., Krathwohl, D.R.(2010). *A Taxonomy for Learning, Teaching, and Assessing : A Revision of Bloom's Taxonomy of education Objectives*. Alih Bahasa : Agung Prihantoro. Kerangka lNdasan untuk Pembelajaran, Pengajaran dan Asesmen Revisi Taksonomi Pendidikan Bloom. Yogyakarta : Pustaka Pelajar.
5) Anderson, J. (2009). Physics Curiculum Development and the Role of Problem Solving. Prosiding ACSA National Conference.Sydney.
6) *Aras, A.(2020).* Model Pembelajaran Means-Ends Analysis dalam Menumbuhkembangkan Kemampuan Problem Solving dan Productive Disposition. Al-Kawarizmi, *Jurnal Pendidikan MIPA*, 8(2), 231-240.
7) Arends, R. I. (2012). *Learning To Teach*. New York : McGraw-Hill.

8) Arslan, M. (2002). The influence of teaching note-taking and information mapping on learning and recalling in science. *turkish online journal of educational technology*, 5(2), 56-63. file:///c:/users/user/downloads/the_influence_of_teaching_note-taking_an%20(1).pdf.
9) Atimi, N. D., Afandi, A., & Tenriawaru, A. B. (2023). The effect of mnemonics method on students'retention and learning outcomes in the learning of biology. *Biosfer: Jurnal Pendidikan Biologi*, 16(2), 296-303. https://doi.org/10.21009/biosferjpb.2800
10) Bakken, J. P. (2011). Mnemonic strategies: Success for the young-adult learner. *The Journal of Human Resource and Adult Learning*, 7(2), 79. Diunduh di http://www.hraljournal.com/Page/9%20Cynthia%20G.%20Simpson.pdf.
11) Braganca. F.(2020). *Basic Principles of Problem-Solving.* https://www.linkedin.com/in/fernandobraganca?trk=article-ssr-frontend-pulse_publisher-author-card
12) Borg.W.R & Gall.M.R. (2007). *Educational Research. An Introduction (8th Edition).* Boston : Pearson Prentice Hall. Creativity Asia. (2017). *Why problem solving skills are critical for students*? https://www.vis10dwarka.com/blog/why-problem-solving-skills-are-critical-for-students
13) Creswell, J.W. (2013). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (3rd ed*)*, Boston : Pearson Prentice Hall.
14) Dewi Sartika & Nur Aisyah. (2018). Analyzing Students' Problem Solving Difficulties on Modern Physics. *2nd International Conference on Statistics, Mathematics, Teaching, and Research*. Doi :10.1088/1742-6596/1028/1/012205
15) Docktor, J.L., Strand, N.E, Mestre, J.P.(2015). Conceptual Problem Solving in High School Physics. Physical Review Special Topics, *Physics Education Research*, vol. 11(2), 1-8.
16) Docktor , J.L., Mester, J.P. (2014). Synthesis of discipline based education research in physics. *Physics Education Research*, Vol. 10(2), 2-10.
17) Dwijayanti, P., Yulianti, D. (2010). Pengembangan Kemampuan Berpikir Kritis Mahasiswa Melalui Pembelajaran Problem Based Instruction pada Mata Kuliah Fisika Lingkungan. *Jurnal Pendidikan Fisika Indonesia*, vol. 6 (1), 110-117.
18) Eggen, P., Kauchak, D. (2012). *Strategies and Models for Theachers : Teaching Content and Thinking Skills.* Alih Bahasa : Satrio Wahono. Strategi dan Model Pembelajaran, Mengajar Konten dan Keterampilan Berpikir. Jakarta : PT Indeks Permata Puri Media.
19) Ekici, D. I. (2016). Examination of Turkish Junior High-School Students Perceptions of the General Problem-Solving Process. *International Education Studies*, 9(8), 159-170.
20) Elma. (2018). Penerapan Model Pembelajaran Problem Solving untuk Meningkatkan Kemampuan Berpikir Kreatif Fisika Siswa. *Jurnal Pendidikan Fisika Universitas Muhammadiyah Makassar*. 6(1), 65–78.
21) Fathiah, Kaniawati, I. & Utari, S. (2015). Analisis Didaktik Pembelajaran yang dapat Meningkatkan Korelasi antara Pemahaman Konsep dan Kemampuan Pemecahan Masalah Siswa SMA Materi Fluida Dinamis. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 1(1), 111-118.
22) Fissore, C., Marchisio, M., Roman, F., & Sacchet, M. (2021). Development of problem solving skills with Maple in higher education, *Communications in Computer and Information Science*, vol 1414. Springer, Cham. https://doi.org/10.1007/978-3-030-81698-8_15
23) Foshay, R. (1998). *The Need to Teach Problem Solving*. Indiana University: TRO Learning, Inc.
24) Hong, J. C., Chen, M. Y., Wong, A., Hsu, T. F., & Peng, C. C. (2012). Developing Physics Concepts Through Hands-on Problem Solving: A Perspective on A Technological Project Design. International Journal of Technology and Design Education, 22(4), 473–487.
25) Hoyt, J. E., & Winn, B. A. (2004). Understanding Retention and College Student Bodies: Differences between Drop-Outs, Stop-Outs, Opt-Outs, and Transfer-Outs. NASPA Journal, 41(3), 395-417. DOI:10.2202/1949-6605.1351
26) Huda, M. (2013). *Model-model Pengajaran dan Pembelajaran*. Yogyakarta: Pustaka Pelajar.
27) Ince, E. 2018. An Overview of Problem Solving Studies in Physics Education. *Journal of Education and Learning*, 7(4), 191-200.
28) Indahwati, R., Dariyatul Aini, S., Ribowo, D., Jalan Raya Panglegur, A., & Pamekasan, K. (2017). Pengaruh Penerapan Strategi *Means-Ends Analysis* (MEA) dalam Pembelajaran Matematika terhadap Kemampuan Berpikir Kritis Siswa. *Jurnal Inovasi Pendidikan*, Dasar, 4(1), 51–56.
29) Juniyarti, N. (2014). Penerapan Model Pembelajaran *Means End Analysis* (MEA) dalam untuk Meningkatkan Hasil Belajar Siswa. *Jurnal Berkala Ilmiah Pendidikan Fisika*, 2(3), 15-23.
30) Permana, S. G. (2023). The Effectiveness of The Means Ends Analysis (MEA) Model on The Mathematical Problem-Solving Ability of Junior High School Students. *Journal of Research In Science And Mathematics Education (J-Rsme)*, 2(1), 36–48. Doi.Org/10.56855/Jrsme.V2i1.6

31) Permatasari, N. Y., Jauhariyah, N. R., Rohmah, S. N., Fisika, J., Matematika, F., Ilmu, D., Alam, P., Surabaya, U. N., & 60231, S. (2019). Penerapan Strategi Means Ends Analysis (Mea) Untuk Meningkatkan Problem Solving Siswa. *Seminar Nasional Fisika (SNF) 2019*
32) Gok, T. & Silay, I. (2010). The Effect of Problem Solving Strategies on Students Achievement, Attitude and Motivation. *Latin-American Journal of Physics Education*, 4(1), 7-21.
33) Lubin, J & Polloway, E. A. (2016). Mnemonic instruction in science and social studies for students with learning problems: A review. *Learning Disabilities: A Contemporary Journal*, 14(2), 207-224. Diunduh di https://files.eric.ed.gov/fulltext/EJ1118431.pdf.
34) Lupita, R. (2019). *Identifikasi Kemampuan Menyelesaikan Ill dan Well Structured Problem dalam Pembelajaran Fisika Pokok Bahasan Teori Relativitas di Jember*. Tesis (Tidak dipublikasikan). http://repository.unej.ac.id/handle/123456789/92500
35) Maries, A. & Singh, C.(2023). Helping Students Become Proficient Problem Solvers Part I: A Brief Review. *Educational Science*, 13(2), 156-166. https://doi.org/10.3390/educsci13020156
36) Marshall, M.(2022). *Benefits of Problem-Solving in the K-12 Classroom.* https://www.vis10dwarka.com/blog/why-problem-solving-skills-are-critical-for-students
37) Mehadi, R.M.(2019). 21st Century Skill "Problem Solving": Defining the Concept. *Asian Journal of Interdisciplinary Research*, 2(1).71-81.
38) Mocko, M., Lesser, L. M., Wagler, A. E., & Francis, W. S. (2017). Assessing effectiveness of mnemonics for tertiary students in a hybrid introductory statistics course. *Journal of Statistics Education*, 25(1), 78-91. DOI: https://doi.org/10.1080/10691898.2017.1294879.
39) Pardimin, P., & Widodo, S. A. (2017). Increasing Skills of Student in Junior High School to Problem Solving in Geometry With Guided. *Journal of Education and Learning (EduLearn)*, 10(4), 390-395.
40) Payne, L. (2024). "*Means-Ends Analysis*". *Encyclopedia Britannica*, 1 Sep. 2023, https://www.britannica.com/science/means-ends-analysis. Accessed 5 January 2024.
41) Pólya, G. *(1945). How to Solve It. Princeton University Press.*
42) Reddy, M.V.B.(2017). Students Problem-Solving Difficulties and Implication in Physics: An Empirical Study on Influencing Factors. *Journal of Education and Practice*,18(14), 58-61. https://www.researchgate.net/publication/334283031
43) Riadi, M. (2020). *Model Pembelajaran Means-Ends Analysis* (MEA). https://www.kajianpustaka.com/2020/10/model-pembelajaran-means-ends-analysis.html
44) Rotherham, A. J. & Willingham, D. T. (2009). 21st Century Skills: The Challenges Ahead. *Educational Leadership*, 67(1): 16-21
45) Safitri, A. N., Sari, R., & Wahyuni, S. (2017). The Influences of Mathematics Ability toward Physics Learning in Senior High School Based on an Authentic Assessment System. *International Journal of Learning and Teaching*, 3(1), 11–14.
46) Sekarpratiwi, F. K., Ngurah M.D.P., & Agus, Y. (2018). Analisis Kemampuan Representasi Diagram Bebas Benda pada Materi Hukum Newton. *Unnes Physics Education Journal*, 7(2), 86-93.
47) Scruggs, T. E., & Mastropieri, M. A. (2000). The effectiveness of mnemonic instruction for students with learning and behavior problems: An update and research synthesis. *Journal of Behavioral Education*, 10(2-3), 163-173. Diunduh di https://link.springer.com/article/10.1023/A:1016640214368.
48) Uno & Umar.(2014). *Mengola kecerdasan dalam pembelajaran: sebuah konsep pembelajaran berbasis kecerdasan*. Jakarta: Bumi Aksara.
49) Walker, J. (2008). *Halliday and Resnick fundamental of physics extended eight edition*. New Jersey: John Wiley and Sons (Asia) Pte Ltd.
50) Widodo, T & Kadarwati, S. (2013). High Order Thinking Berbasis Pemecahan Masalah Untuk Meningkatkan Hasil Belajar Berorientasi Pembentukan Karakter Siswa. *Cakrawala Pendidikan*, 32(1), 161-171.
51) Yandri, A. (2022). Peran Guru dalam Menghadapi Inovasi Merdeka Belajar. https://gurudikdas.kemdikbud.go.id/news/peran-guru-dalam-menghadapi-inovasi-merdeka-belajar
52) McCabe, J. A., Osha, K. L., Roche, J. A., & Susser, J. A. (2013). Psychology students' knowledge and use of mnemonics. Teaching of Psychology, 40, 183– 192. http://dx.doi.org/10.1177/0098628313487460