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The Analysis of the Problems Solving Pattern on Wave Concept of the Physics Teachers' Candidate

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Abstract

The purpose of this research is to find the pattern of problem-solving of the wave concept. Qualitative research methods have been used. Think-aloud methods, essay tests, and interviews were used in data collection. Data analysis used qualitative analysis techniques. The results of the pattern of wave problem-solving by prospective teachers are formula-based methods, followed by P-prim and a small amount using analytical thinking. Difficulties in the effect of phase changes on the shape and value of displacement, and the propagation of string waves on the stationary wave of the Meld's experiment. From the analysis, it is necessary to learn multi-representation of the concept of waves based on the type of problem-solving pattern was used. The benefits of research as input for monitoring the curriculum of the study program and increasing the interaction of wave physics learning.

Key words: problem solving pattern, wave concept, physics teachers' candidate

INTRODUCTION

The quality of human resources, especially educators, is still an interesting subject of research in the field of education in the world. The issue of teachers which is one of the components of college graduates needs serious attention. Students who take education courses join the program according to the chosen field, including physics education courses. There are several interesting areas of study; one of them is on understanding the wave concept as common knowledge for physics teacher candidates before they are become a teacher in the school. Some studies on epistemology in wave learning have been conducted to prepare physics teachers' candidate. According to the findings (Evagorou *et al*., 2015) stated studies in learning epistemology may help to explain the cognitive state of the students as part of the learning outcomes and provide input for the preparation of a more effective curriculum and instructional improvement. In the curriculum of physics teachers' candidate, wave concept is programmed for some enrichment courses including mechanics, electricity and magnetism, thermodynamic and modern physics; so that students can understand the concepts of physics in a comprehensive manner.

For physics teachers' candidate in senior high schools, they should have the ability to transform the nature of wave which is semi-abstract and abstract into a scientific language that is easily understood by students (Bing, 2008). This is aligned with the role of teachers as agents of change which is to be able to understand the development of science through scientific explanation and to convey it to the students through pedagogical explanation (Goh & Yusuf, 2017). Having observed the strategic role of teachers' candidates who have the responsibility to educate the children of the nation, then the matter is worth the attention, specifically on matters related to the competence of physics teacher candidates (Nugroho, 2010; Virtanen *et al*., 2017).

The course of waves is presented in the

form of abstract mathematical language and illustrations, which both important to represent the concept of waves. The mathematical equation is used to represent the wave as a function that contains some variables, differential equations, and special functions. The physical characteristics which are expressed in abstract mathematical forms is intended for the wave material to be more information-rich, because of several concepts that can be described and explored. However, students should be required to understand the physical meaning contained in the mathematical expression.

Fakcharoenphol *et al.* (2015) states that difficulties experienced by students in solving problems using mathematics in physics problems may come from a lack of mathematical knowledge necessary for problem-solving, or students had to acquire relevant knowledge of mathematical but are not always able to use it appropriately. Therefore, we need strategies that can help students to use the resources. The research by Morphew (2021) report that distinguishes non-productive epistemology as thinking just by remembering formulas and numerical answers, and epistemology, which is a productive thinking accompanied by efforts to build the idea by linking the facts and concepts of physics (Bahtiyar & Can, 2016). Epistemology, which is formula oriented, is categorized as non-productive because students do not develop reasoning. Fakcharoenphol *et al.* (2015) also reveals some difficulties encountered by students in using mathematics in physics subject. Based on the research (Murphy *et al.*, 2012; Bing, 2008) these examines the use of advanced mathematics in physics subject. Research on the wave has been done by using dynamic transfer model; the results reveal that elements of wave mechanics of student knowledge can be mapped (Bonk & Wiley, 2020). The result of a study from Wang (2021) stated that the students have difficulties on mechanical superposition, string wave reflection, and propagation of sound waves. Another difficulty is the understanding of mathematical equations to explain physical aspects of the wave.

Epistemology analysis can give idea of the students' mindset in to understand, and to apply a concept and its constraint naturally. This information will be an important ground in the improvement of learning and curriculum development for physics teacher candidates. This study discusses how the problem-solving pattern is used by students in solving problems of waves, and how the students' difficulties in accessing waves concept is described.

Research on sound waves to improve the curriculum of physical education colleges has been conducted (Wang, 2021). Research on wave learning, especially wave phenomena (general characteristics) for the students is continued. Research on waves by using pedagogical subject matter has been done (Johnson, 2019; Park, 2020) who adapted the model of educational reconstruction developed by Wang (2021). This model includes three components, namely the conceptions of the understanding, scientific clarification, and learning development. This model emphasizes to the effects empirical studies results on the analysis of content based on the unit analysis and to the target destination achievement. The result of the gradual investigation on students' perception and content structure analysis is essential in building the knowledge of students (Park, 2020). The result of another study conducted (Krell *et al*., 2014) concerning the use of analogy in understanding the concept of wave has managed to uncover several things, namely (a) the analogy of building thinking induction effect on differences in understanding the concept of wave, and (b) the meaning of the proper illustration which facilitates students in understanding the concept of waves.

The topic on sound waves propagation has been revealed in researchs (Calik *et al*., 2011; Robinson *et al*., 2020), they developed a mental model assessment for sound propagation topic. Inventory assessment model which has been developed is called Formative Assessment of Mental Models of Sound Propagation (FAMM-Sound). Multiple choice assessments are developed to identify the learners' mental model. Learning takes place effectively to describe the students' mental model of the sound wave propagation material.

The notion of constructivism states that a

student constructs new knowledge based on what their thinking. The role of teachers in the constructivist paradigm is to create an environment to help students performing this construction accurately and effectively. Knowledge of the students thinking construction in shaping the new knowledge will help teachers determining the structure and content of existing knowledge on students, and how students use it to construct new knowledge.

Based on the finding (Asikainen & Hirvonen, 2014) those the reasoning approach in understanding the physics includes two models, namely knowledge of physical phenomena based on an intuitive approach, and mathematical knowledge based on formal approach. Intuitive sensitivity about the physical mechanism is formed from the experience of everyday life, while the mathematical sensitivity is usually trained within teaching and learning process. Focus on this research is to construct of epistemic belief about the nature of knowledge. We argue that analytical grounded in a pragmatic, sociocultural perspective is well placed to explore this epistemic construct using discourse-centric technologies.

This epistemology study is expected to be used as a ground to view the wave concept formation and development of students' logical reasoning. Learning to equip teacher candidates does not simply rely on conceptual understanding but also building the habit of thinking like a scientist or expert thinking. The guided inquiry learning by applying the values of conservation characters to effectives improve understanding of the concept of high school students (Sarwi *et al.,* 2018).

Inquiry guided learning by applying the values of conservation characters is to effective develop their scientific work skills.Overview on the shifts of logical reasoning refers to the habit of thinking from expert and novice in solving problems. Based on the result of the research (Wolff *et al*., 2015; Sarwi *et al*., 2017), it can be concluded that experts focused on learning in the classroom and the teacher's ability to influence, whereas novices more concerned with maintaining discipline and behavioral norms. An overview of the differences between novice and expert as shown in Table 1. The signs which are presented in Table 1 are then used to analyze the shift of reasoning model in wave solving problems for physics teacher candidates in semester two and four.

The research reveals how cognitive are the process of students in understanding the concept of wave phenomena, superpositions and wave propagation in the medium. Through analysis of the epistemology on the concept of the wave, how the students can access and analysis the physics teacher candidates' difficulty to form the wave knowledge to solve the problems has been revealed.

METHOD

This study was designed using qualitative research approach which the research aimed at obtaining scientific proofs on theoretical explanation, rules, models, a pattern or a new postulate which supports a process of applied research and technology (Creswell& Clark, 2018). The research location was study program of Physics Education at State University in Central Java, Indonesia. Differences in the way of thinking of novice and experts are presented in Table 1.

Table 1. Differences in Ways of Thinking and Problem Solving between Novice and Experts (Ertmer *et al*., 2009; Fakcharoenphol, *et al.,*2015).

Domains	Novice	Expert
Thinking Representation	Reporting the surface features using the existing sentences and labeling, label links surface variables, seeing the problem from one aspect	Framing logically using his words, label links the key concepts, see the problem from various aspects
Review of the issue	Focus on concrete things, taking information from the visible value, describing the problems of errors	Focus on abstract principles, interpreting the received information, look at the issue from the basic principles
Problem linkage	Problems are collected separately,	Problems are recorded coherently,

Domains	Novice	Expert
	presenting the issue but there is no explanation about problems linkage	organizing and creating the problems linkage
Problem Solving	Started by focusing on what they do not know in the question without regarding the data, and then try to solve the problems (*backwards).*	Started by creation inferences based on the known data, and then the problems are solved through problem conceptualization (*forward*)

The subjects were students of physics education department who underwent basic physics courses in the second semester and students participating in the wave course in four semesters. The research subjects are 14 physics teachers' candidates at State University in Central Java. Respondents were grouped into the second semester student, referred as the Group I (six students), and fourth semester students, referred as the Group II (eight students). The basis of those respondents at both levels was intended to make the research results can be mapped based on cognitive development in solving the problem of the wave concept as the outcome of the debriefing process on physics teacher candidate.

This study used the theoretical sampling. The numbers of students assigned is based on the consideration of the invention theory by taking into account the variability of the subject until it reached a saturation state. The data was collected based on the research questions which were formulated. Research subjects were not randomly selected, but by considering the ability to communicate for the disclosure of thinking patterns to be recorded properly. Selection of sampling was based on the theoretical sampling and the research objectives. Definition of sampling in qualitative research was not intended for generalization purposes.

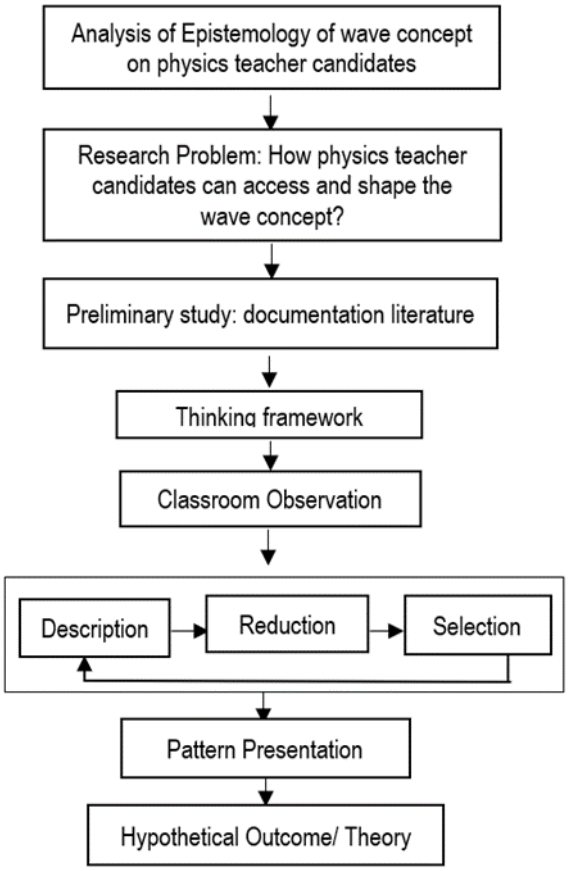

Figure 1. The Developed Research Procedure

This research was conducted using the qualitative approach with a cross-sectional design that aimed to discover the essence of phenomena occurred at the same time. A preliminary study was carried out by using literature review to form the thinking framework before the classroom observation was conducted. Steps in the research were shown in Figure 1.

Data collections were done by using the Think Out Loud (TOL) or also known as think aloud which asked the subjects to solve the problems and to express out loud what they were thinking. Two highlights of the think-aloud methods (Pejuan *et al*., 2012) are the students write or state the consciousness of thinking when solving the problems, and the student must report what they think about at the moments. Based on the proposed procedure (Ertmer, *et al*., 2009; Yoon *et al*., 2020) the process of verbalization of the thought process through five stages. The overall scheme of

verbalization process as shown in Figure 2.

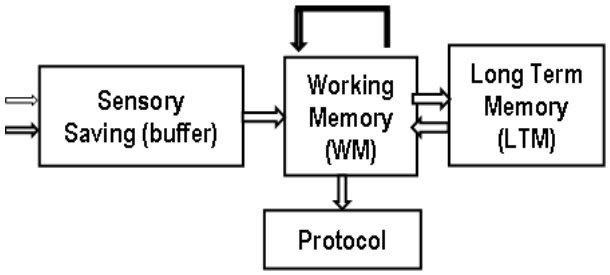

Figure 2. Memory Model during the Process of Verbalization

Think aloud is seen as a method that can minimize the disruption in the thought process as disclosed without the intervention from outside. Unclear information due to verbalization factors was triangulated with a written test and interview. Researchers also conditioned the students to express freely what they were thinking with the language. In qualitative research, the role of the researcher and research instruments were guided by the daily record sheet instruments.

The instruments of data collection in the form of interviews and written tests were used as an exploration model of students thinking when solving the problems. Further analysis of the coding protocol was used to find models of epistemology. The material was explored through the study, including the concept of a wave phenomenon, superpositions, wave mechanics, and wave behavior in the medium. Broadly speaking, the theoretical framework in the process of data analysis is presented in Figure 3 adapted from Rogiers *et al.,* 2020)

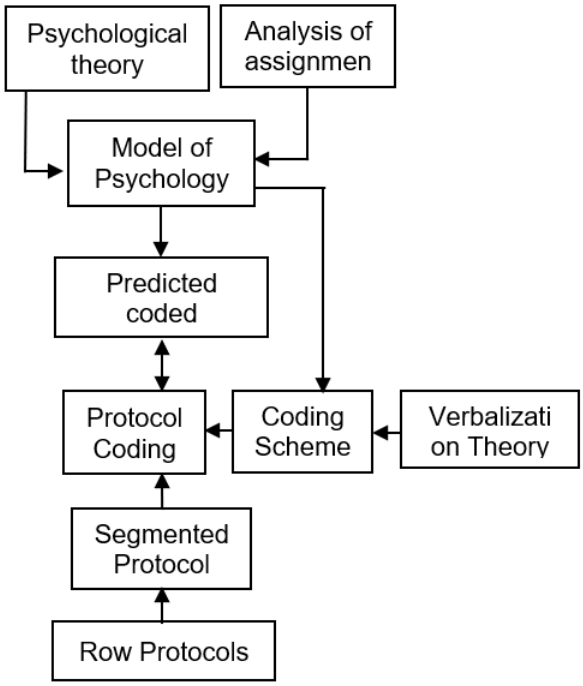

Figure 3. The Process of Data Analysis

RESULTS AND DISCUSSION

Problem solving pattern of the teacher candidate students at State University in Central Java Indonesia was analyzed from the manner of their solved the wave problems and the framework to determine the problem solving was used. The thinking framework of teacher candidate student for problem solving score of travelling wave function as shown in Table 2. Analysis of the problems solving pattern is focused on determining the value of deviation of the wave function.

Table 2. Thinking Framework for Problem Solving Score of Travelling Wave Function

Thinking framework for problem solving score of travelling wave function	Group I (%)	Group II (%)	Average (%)
P-prim	33	12.5	22.75
Formula-Based	50	50	50
Critical thinking	17	37.5	27.25

The concept structure data of physics teacher candidate student for each component achieved by both groups I and II are presented in the following sections. Data regarding three ways of

thinking to solve problems superposition of waves superposition are presented in Table 3.

Table 3. Percentage of Reasoning of Model Group I and II in Understanding the Concept of Wave Superposition

	K1 (%)	K2 (%)	K3 (%)
Group_II	12.5	37.5	50
Group_I	33	50	17

Description: K1 (P-prim), K2 (formula-based), K3 (critical thinking)

Based on the Table 3 shows that group I is dominantly uses the formula-based model and P-Prim for solve the wave superposition problem, whereas group II is dominant to use the critical thinking and formula-based model to solve the question of superposition of waves. As we known, group I is teacher candidate student on second semester. Indeed, the teacher candidate student in this level is not enough ability on comprehensive thinking yet. It's clear to explain why on group I dominant to use formula-based model and P-prim. While on group II, the teacher candidate student has comprehensive thinking already. It's because on group II the teacher candidate student has accepted much information of the wave concept from many subjects on the learning process. That why, on group II was dominantly to use the critical thinking and the formula-based model to solve the waves problem.

The results of the data analysis on the solution of wave problem propagation in the medium are limited to medium of strings, rods, and fluid (water and air). On the concept of wave propagation in the medium of string, the Meld's experiment is conducted. The 64% teacher candidate student of all respondents was explained that the wave form that propagates in a string is influenced by the mass of the string and force. The teacher candidate student still not correlates yet with cross-sectional area of string (if the string is large) and the force which is from the physics quantity such as gravitational force. As we known, there is an important concept that the force was used on the Meld's experiment was determined the wave form is from the mass or load which is tied to a string through a pulley that can move freely. Then, only 36% of teacher candidate student give a respond which is they are make correlation of the load mass (*m*) was hanged on a string through the pulley to move freely. The result of the research on wave concept such as superposition wave and wave propagation in the medium term based and data collection method is presented. Data mastery of the wave concept of the whole matter by the 2nd semester of the respondents as shown in Figure 4.

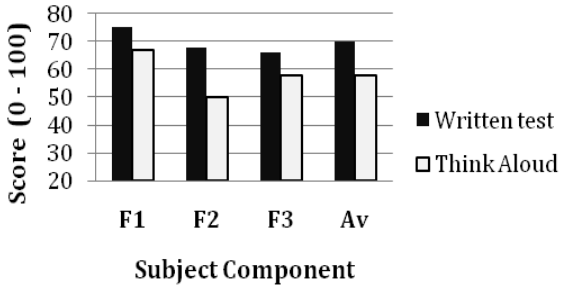

Figure 4. The score of Concept Mastery of Wave Achieved by Students' Semester 2 (F1 (phenomena of travelling wave), F2 (superposition), F3 (wave propagation in the medium), Av (mean score))

Figure 4 shows that mean score of the teacher candidate student has written test result higher than think aloud. It's because the teacher candidate student at second semester still like as senior high school student habit. At the senior high school, assessment of student much easily used written test compared to the think-aloud. The data of concept mastery which includes the three materials achieved by group II (4th semester) is presented in Figure 5.

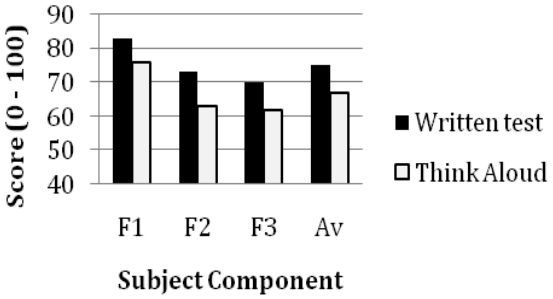

Figure 5. The score of concept mastery of waves achieved by Students' Semester 4
(F1 (phenomena of travelling wave), F2

(superposition), F3 (wave propagation in the medium), Av (mean score))

Figure 5 shows that chart has similar trend to the Figure 4, whereas the average score of teacher candidate for written test result higher than think aloud. However, for score value the concept mastery of teacher candidate student at second semester and fourth semester has different. Based on the data on Figure 4 and Figure 5, it's clear the teacher candidate student at second and fourth semesters were had the good abilities on the solve of the wave problem is used written test compared to the think-aloud on the solve of waves problem. The result was supported that students are faced with irregular problems using a speaking procedure to narrate their thought processes. Reasonable solutions and fewer obstacles have been found by students who have more knowledge (Milbourne & Wiebe, 2018). We assume it's because the teacher candidate student at State University in Central Java need to give some motivation or has confident feeling to communicate the idea as the result of the think-aloud. The main technique of think aloud has been used for recording the aloud opinion and then processed with a judgment to produce research data in the form of scores of the two groups of respondents which are presented in Table 6.

Table 6. The Scores of Concept Mastery of Wave through Think Aloud Method

Group	F1(%)	F2(%)	F3(%)	Av (%)
Group_I	67	50	58	58
Group_II	76	63	62	67

Furthermore, trend of the score of the concept mastery of wave through the think aloud method for group I and group II as shown in Figure 6.

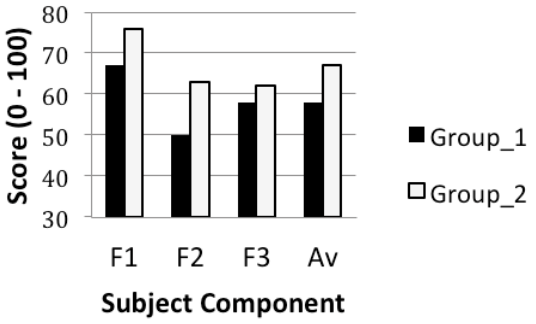

Figure 6. Score of the teacher candidate student for problem solving of wave concept use think aloud of group I and group II

Based on the Figure 6 shows that through think aloud, it provides information that the mastery of the wave concept especially on wave phenomenon and wave superposition is quite different from the scores achieved by the Group I and Group II. The score achieved by both groups have 9 different points, while for the wave superposition is 13 different points. The scores result illustrated in the histogram are almost same (4 points) for wave propagation in the medium, but both are quite low achievement scores.

The result of research in the form of a written test score using essays is presented in this report in Table 7. The data in Table 7 is then displayed with a histogram illustration presented in Figure 7.

Table 7. The Scores Achieved by Respondents of Group I and Group II through Written Test Method

Group	F1(%)	F2(%)	F3(%)	Av (%)
Group I	75	68	66	70
Group II	83	73	70	75

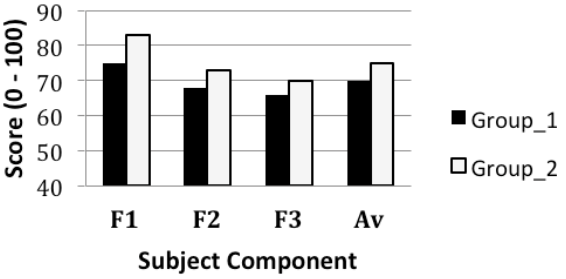

Figure 7. Score of the teacher candidate student for problem-solving of wave concept use eassay test of group I and group II

Based on Figure 7 that its clear the score result which is achieved by Group I and Group II based on an essay of written test instrument has shown an increase as compared with the scores collected from the think aloud method. These average scores achieved by Group I and Group II for all wave concepts are 70 and 75 respectively.

The solving pattern, which is used by the respondent to overcome the function value of wave deflection through think aloud technique, is presented in Table 3. In solving the problem, respondents use the frame of the P-Prim, formula-

based, and analytical thinking. The result of the data analysis based on the recording process by using the handy cam and voice recorder about how the manner of solving on the wave function as shown in Table 3. The teacher candidate student as respondent in this process was choose for using equation and analytical thinking compared to use the P-Prim method (Murphy *et al*., 2017). There are 50% of teacher candidate student on both groups choose for using equation to solve the wave concept problem compared to use the analytical thinking. According to way were chosen of two groups on the way of problems solving ability, it's can be said that the teacher candidate student not understand the wave concept very well. In other word, can be said that the teachers' candidate students were had less attention on the process learning especially on the wave concepts (Sarwi *et al.,* 2018). Furthermore, the teacher candidate student also could not mention or explain the x and t variable on the wave function diagram. Last, the teacher candidate student not doing analysis on the wave function which is they are uses at the solving of the wave problem. Based on above explanation, can be concluded that the teachers' candidate students are applying the backward pattern on solve of the wave problems.

Approach on the understanding of the physics concept like that is expressed by Asikainan & Hirvonen (2014), which is includes two models, namely knowledge of physical phenomena based on an intuitive approach, and mathematical knowledge based on formal approach. Intuitive sensitivity about the physical mechanism is formed from the experience of everyday life, whereas the sensitivity of mathematical modeling the wave concept is usually trained in learning. The experience of prospective teachers in laboratory practice makes an important contribution to building to the teacher candidate student knowledge. Active learning process of teacher candidate students determines the quality of mastering the concept and strengthens the knowledge that has been previously owned (Sarwi *et al*., 2017; Virtanen *et al*., 2017).

In this research, the teacher candidate student shows different manner on the how to solve the wave concept problem, i.e 37.5% of the teacher candidate student on group II was used the analysis of thinking patterns, however, there are still have 50% or 4 teacher candidate students using equation for solve the wave concept problem. It's because the development of the cognitive psychology of the teachers' candidate students has a little problem, where the abstract thinking including reasoning, the analysis and synthesis, has not dominantly developed by students yet. Structure concept data of physics teacher candidate student for each component which is achieved both od Group I and II are presented in the following sections. The data of four ways of thinking to solve problems of wave superposition concept is presented in Table 3. The result of data analysis shows that the first group is more dominant in using formula-based pattern and P-Prim pattern. Whereas Group II was dominantly uses of the analytical thinking pattern and formula-based pattern to solve the question of superposition of waves.

Wave superposition means only the sum of two waves, but the reality in the daily life, superposition is the sum of many waves. Indeed, in the text books the superposition wave usually was explained in the simple concept such as described with two waves only (Calik *et al*., 2010; Wang, 2021) were stated that students have difficulty according to the superposition and reflection wave form on mechanical waves and sound wave propagation. Another research states that a physics lesson, students are thinking about not connection between fact on the daily life and the concept formula or relationships between concepts which is represented in the form of the equation (Evagorou *et al.*, 2015). Interference as the result of superposition cannot be understood correctly, but the superposition of two waves of the same direction of propagation which has the same amplitude and frequency of both or one of them has been understood very well.

Based on the data analysis of wave propagation on the string and air medium, it shows a lack of understanding of student about the force

which is created by load mass. The load mass has not been studied by the teacher candidate students whether this can directly influence the shape and the number of waves or not. From the wave form that is exhibited at the Meld's experiment, this clearly shows that the number of waves is inversely proportional to the load mass addition.

Sixty four percent of all teacher candidate students as respondents explain that the waveform that propagates in a string is influenced by the mass of the string and force. However, the teacher candidate student make correlation yet between string cross-sectional area and the waveform has linked by a string cross-sectional area (if the string is large) and style that comes from the unexplained physical quantity. However, there is an important concept that the force which determines the waveform is load or mass which is tied to a string through a pulley that can move freely. Then, only 36% of teacher candidate students giving a respond by linking the load which is hanging on the string through the pulley.

Furthermore, four teacher candidate students from 4thsemester can explain correctly that the waveform is determined by the type of string (string mass) and the mass of the suspended load. The result of the overall pattern of problem solving in which students receive is presented in Table 4. The analysis shows that many respondents are still using the pattern of problem solving with backwards thinking to interpret the questions and then exposing the memory experience to determine a solution (Erduran & Kaya, 2018). They are do not use the existing data and perform processing data to determine the answer to a problem. Understanding the concept of wave propagations which includes running, superposition and wave propagation in the medium can be improved by using a cross-check with the written test and interview methods. The result analysis is also strengthened by a brief note on the data collection so that the selection process and the preparation of solving patterns are not biased towards a state of actual respondents (Creswell & Clark, 2018).

Research result in Table 6 shows that the written tests provide information that the mastery of the wave concept phenomenon and wave superposition is quite different from the scores achieved by the Group I and Group II. Scores achieved by both groups for a wave phenomenon different up to 9 points, while the wave superposition has 13 different points. Score of the results illustrated in the histogram is almost same for wave propagation in the medium, but the achievement score is quite low because it has not reached grade B.

Travelling wave concept is not well understood at the time of data collection using think aloud method, because students are a little anxious and worried about their answers if one would have an impact on the quality of the research report. Another factor that affects the quality of the student response is the time of data retrieval which comes a few weeks after the course has ended. These two factors can be overcome by re-reading and review the previous course materials that have been obtained, and the major of students have learned first. This the main factor is to understand the concept of waves in memory that has not reached the level of medium or long-term memory (Huang *et al*., 2019). Professional competence for prospective teachers is essential in the practice of learning. Professional competence in mastering the field of science is very important and fundamental for the teaching profession. Other related research that the professional development is needed to sustain for teachers are novice or experienced (Mohan *et al*., 2017).

The scores result achieved by first and second based on the essay written test instrument shows an increase compared with the scores collected from the think aloud method. The average score which has been achieved by first and second for all waves materials are 70 and 75 respectively. Differences in scores for all concepts tested on the waves are at intervals of five points to six points. Changes in the achievement of these scores indicate that the respondent have tried to improve the mastery of the wave concept in the think aloud method and the conceptual change in physics (Calik, *et al.,* 2010). Scores achieved by both groups have not shown a satisfactory level of

competence to meet the target because it is still in the grade BC and grade B, based on scoring guides from the University. However, achievement scores with think aloud method to switch on the written test essays for travelling wave phenomena obtained by both groups show significant improvement from the score of 67 to 75 (Group I) and a score of 76 to 83 (Group II).

The Credibility is manifested by researchers in the product efforts were validity and representatively instruments. Researchers also conduct triangulation to validate the data of think aloud, a written essay test, and interview methods. Transferability in research which is shown by the general conclusions or patterns can be inferred from the model of reasoning in wave solving problems done by the teacher candidate students. Transferability size is determined by the application or the use of research results to other situations. Model reasoning and problem-solving patterns that are found should have the strength when this is applied to other subjects. Although when it is viewed from the aspect of solving trends or patterns, then in the analysis of long lasting, results may be subject to change.

CONCLUSION

Based on the results and discussion that have been presented, the conclusions are as follow: physics problem solving pattern which is displayed by most students is a technique based on the formula, followed by P-Prim techniques, and subsequently a fraction using analytical thinking techniques.

The results of the pattern of wave problem-solving by prospective teachers are formula-based methods, followed by P-prim and a small amount using analytical thinking. Difficulties in the effect of phase changes on the shape and value of displacement, and the propagation of string waves on the stationary wave of the Meld's experiment. From the analysis, it is necessary to learn multi-representation of the concept of waves based on the type of problem-solving pattern was used. The benefits of research as input for monitoring the curriculum of the study program and increasing the interaction of wave physics learning.

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REFERENCES

Asikainen, M.A. & Hirvonen, P.E. (2014). Probing Pre- and In-service Physics Teachers' Knowledge Using the Double-Slit Thought Experiment. *Sci & Educ* **23,** 1811–1833 (2014). https://doi.org/10.1007/s11191-014-9710-1

Bahtiyar, A. & Can, B. (2016). An-Investigation of Problem Solving Skill of Pre-Service Science Teacher. *Educational Research and Review*, 11(23) 2108-2115

Bing, T.J. (2008). *An Epistemic Framing Analysis of Upper Level Physics Students' Use of Mathematics*. Unpublished Doctor of Philosophy's Dissertation, Maryland University, College Park

Bonk, C.J., & Wiley, D.A. (2020). Preface: Reflections on the waves of emerging learning technologies. *Education Tech Research Dev* **68,** 1595–1612. https://doi.org/10.1007/s11423-020-09809-x

Çalik, M., Okur, M., & Taylor, N. (2011). A Comparison of Different Conceptual Change Pedagogies Employed Within the Topic of "Sound Propagation." *Journal of Science Education and Technology, 20(6), 729-742.* doi:10.1007/s10956-010-9266-z

Calık, M., Kolomuc¸ A. & Karagolge Z (2010). The effect of conceptual change pedagogy on students' conceptions of rate of reaction. *J Sci Educ Technol,* 19:422–433

Creswell, J.W. & Clark, V.L.P. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* Singapore: SAGE Publications, Inc.

Ertmer, P.A. Stepich, D.A. Flanagan, S. Karoglu, A.K. Reiner, C. Reyes,L., Santone, A. & Ushigusa, S.

(2009). Impact of Guidance on the Problem-Solving Efforts of Instructional Design Novices. *Performances Improvement Quarterly*, 21(4), 117-132.

Erduran, S. & Kaya, E. (2018). Drawing Nature of Science in Pre-service Science Teacher Education: Epistemic Insight Through Visual Representations. *Res. Sci. Educ.* 48, 1133–1149. https://doi.org/10.1007/s11165-018-9773-0

Evagorou, M., Erduran, S. & Mantyla, T. (2015). The role of visual representations in scientific practices: from conceptual understanding and knowledge generation to seeing how science works. *International Journal of STEM Education*, 2(11):1-13; DOI 10.1186/s40594-015-0024-x

Fakcharoenphol, W., Morphew, J.W. & Mestre, J.P. (2015). Judgments of physics problem difficulty among experts and novices. *Phys. Rev. ST Phys. Educ. Res*. **11**, 020128, 1-14. http://dx.doi.org/10.1103/PhysRevSTPER.11.020128

Goh, P. S. C. & Yusuf, Q. (2017). Validation of the Malaysian Version of the Teacher Education Program Coherence Questionnaires. *Australian Journal of Teacher Education,* 42(12), 42-59

Huang, R., Spector, J.M. & Yang, J. (2019). *Educational Technology, A Primer for the 21st Century.* Singapure: Springer Nature Singapore.

Johnson, E.K. (2019). *Waves*: Scaffolding Self-regulated Learning to Teach Science in a Whole-Body Educational Game. *J Sci Educ Technol* **28,** 133–151. https://doi.org/10.1007/s10956-018-9753-1

Krell, M., Reinisch, B., & Krüger, D. (2014). Analyzing Students' Understanding of Models and Modeling Referring to the Disciplines Biology, Chemistry, and Physics. *Research in Science Education, 45(3), 367–393.* doi:10.1007/s11165-014-9427-9

Milbourne, J., & Wiebe, E. (2018).The Role of Content Knowledge in Ill-Structured Problem Solving for High School Physics Students. *Res Sci Educ* 48, 165–179. https://doi.org/10.1007/s11165-016-9564-4

Murphy, P.K., Alexander, P.A., Greene, J.A. & Hennessey, M.N. (2012). Examining epistemic frames in conceptual change research: implications for learning and instruction. *Asia Pacific Educ. Rev*., 13: 475-486; DOI 10.1007/s12564-011-9199-0

Murphy, P.K., Firetto, C.M. & Greene, J.A. (2017). Enriching Students' Scientific Thinking Through Relational Reasoning: Seeking Evidence in Texts, Tasks, and Talk. *Educ Psychol Rev* 29, 105–117. https://doi.org/10.1007/s10648-016-9387-x

Morphew, J.W. (2021). Changes in metacognitive monitoring accuracy in an introductory physics course. *Metacognition Learning* **16,** 89–111. https://doi.org/10.1007/s11409-020-09239-3

Mohan, P.P., Lingam, G.I. & Chand, D.D. (2017). Teachers' Perceptions of the Impact of Professional Development on Learning and Teaching in a Developing Nation. *Australian Journal of Teacher Education*, 42(1), 17-33.

Nugroho, S.E. (2010). *Epistemological Analysis of Electricity and Magnetism Concepts on Students of Physics Teacher Candidates*. Dissertation (unpublished), Bandung: Universitas Pendidikan Indonesia

Pejuan, A., Bohigas, X., Jae´n, X. & Periago, C. (2012). Misconceptions About Sound Among Engineering Students. *J Sci Educ. Technol.,* 21:669–685. DOI 10.1007/s10956-011-9356-6

Park, M. (2020). Students' problem-solving strategies in qualitative physics questions in a simulation-based formative assessment. *Discip Interdscip Sci Educ Res* **2,** 1. https://doi.org/10.1186/s43031-019-0019-4

Robinson, F.J., Reeves, P.M., Caines, H.L. & Claudia De Grandi, C. (2020). Using Open-Source Videos to Flip a First-Year College Physics Class. *J Sci Educ Technol* **29,** 283–293. https://doi.org/10.1007/s10956-020-09814-y

Rogiers, A., Merchie, E. & Van Keer, H. (2020). What they say is what they do? Comparing task-specific self-reports, think-aloud protocols, and study traces for measuring secondary school students' text-learning strategies. *Eur J Psychol Educ* **35,** 315–332. https://doi.org/10.1007/s10212-019-00429-5

Sarwi, S., Supardi, K.I. & Linuwih, S. (2017). Physics Structure Analysis of Parallel Waves Concept of Physics Teacher Candidate. *Journal of Physics: Conf. Series* **824**,012011, doi:10.1088/1742-6596/824/1/012011

Sarwi, S., Hidayah, N. & Yulianto, A. (2018). Guided inquiry learning model to improve the conceptual understanding and scientific work skills of high school students in Central Java. *Journal of Physics: Conf. Series* **1170,** 012083; doi:10.1088/1742-6596/1170/1/012083

Virtanen, P., Niemi, H.M. & Nevgi, A. (2017). Active Learning and Self-Regulation Enhance Student Teachers' Professional Competences. *Australian Journal of Teacher Education,* 42(12), 1-22

Wolff, C.E., van de Bogert, N., Jarodzka, H. & Boshuizen, H.P.A. (2015). Keeping an Eye on Learning: Differences Between Expert and Novice Teacher's Representations of Classroom Management Events. *Journal of Teacher Education*, 66(1), 68-85. https://doi:10.1177/0022487114549810

Wang, CY. (2021). Differences in perception, understanding, and responsiveness of product design between experts and students: an early event-related potentials study. *Int J Technol Des Educ* **31,** 1039–1061. https://doi.org/10.1007/s10798-020-09592-z

Yoon, JS., Boutis, K., Pecaric, M.R., Fefferman, N.R., Ericsson, K.A. & Pusic, M.V. (2020). A think-aloud study to inform the design of radiograph

interpretation practice. *Adv in Health Sci Educ* 25, 877–903. https://doi.org/10.1007/s10459-020-09963-0