Pre-service physics teachers’ thinking styles and its relationship with critical thinking skills on learning interference and diffraction

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Abstract. This research is a survey that describes the profile of pre-service physics teachers (PPTs)’ thinking styles and critical thinking skills when they learning interference and diffraction. This survey involved 46 PPTs of fifth semester at one of the universities in Ternate city. Data related to PPTs’ thinking styles were collected through the Yanpiaw Creative-Critical Styles Test, while the data related to PPTs’ critical thinking skills were collected through tests of critical thinking skills. Data were analyzed by using quantitative descriptive technique. Based on the results of the data analysis, it was concluded that generally the PPTs’ critical thinking skills for the group of superior critical, critical and balance thinking styles can be categorized as low, while for the group of creative thinking style can be categorized as high. The map of thinking styles and critical thinking skills will be used as a reference in developing a model of gamification in the physics learning context.

1. Introduction

Thinking is generally assumed to be a cognitive process, a mental act by which knowledge is acquired. Based on the processes, the model of thinking skills can be classified into; a) basic processes: as causation, transformations, relationships, classification and qualifications, b) complex thinking processes: as problem solving, decision making, critical thinking and creative thinking [1].

Critical thinking (CT) is one aspect in ways of thinking in 21st century skills [2]. This thinking skill is one of the most important skills to be trained for pre-service physics teachers (PPTs). CT was correlates significantly with the students’ self-efficacy and success in a course [3], has a positive impact on student learning [4], an important component of the process of problem solving [5].

CT is reasonable and reflective thinking focused on deciding what to believe or do. CT so defined involves both dispositions and abilities. As abilities, CT consist of indicators; a) elementary clarification;
focusing on a questions, analyzing arguments, asking and answering questions of clarification and challenge, b) basic support; judging the credibility of a source, observing and judging observations report, c) inference; deducting and judging deductions, inducing and judging inductions, making and judging value judgment, d) advanced clarification; defining terms and judging definitions; three dimensions, identifying assumptions, e) strategy and tactic; deciding on an actions, interacting with others [6].

CT is judging in a reflective way what to do or what to believe [7]. The core of CT skills and sub-skills consist of; a) Interpretation; categorization, decoding significance and clarifying meaning, b) Analysis; examining ideas, identifying arguments and analyzing arguments, c) Evaluation; assessing claims and assessing arguments, d) Inference; querying evidence, conjecturing alternatives and drawing conclusions, e) Explanation; stating results, justifying procedures and presenting arguments, f) Self-regulation; self-examination and self-correction [8].

CT is a complex process of deliberation which involves a wide range of skills and attitudes. It includes; a) identifying other people’s positions, arguments and conclusions, b) evaluating the evidence for alternative points of views, c) weighing up opposing arguments and evidence fairly, d) being able to read between the lines, seeing behind surfaces, and identifying false or unfair assumptions, e) recognising techniques used to make certain positions more appealing than others, such as false logic and persuasive devices, f) reflecting on issues in a structured way, bringing logic and insight to bear, g) drawing conclusions about whether arguments are valid and justifiable, based on good evidence and sensible assumptions, h) presenting a point of view in a structured, clear, well-reasoned way that convinces others [9].

Physics learning is one way to develop PPTs’ CT skills. Several efforts have been done to achieve these goals such as the use of virtual laboratory [10], using real life video evaluation with e-learning system [11], experiments base on problem solving [12], interactive multimedia [13], guided discovery learning method [14] and problem-based learning with computer simulation [15].

One of the topics in physics that can be used as a way to develop CT skills is the topic of interference and diffraction. However, preliminary study has shown that the PPTs’ concept mastery on this topic is still categorized as low [16]. The lack of concept mastery is caused by the less of PPTs’ engagement in the learning activities so that the development PPTs’ CT was not optimal.

Researchers have shown that to improve student’s engagement in learning activities at higher education levels is through gamification [17-22]. Gamification is defined as the use of game design elements in non-game context [23-25]. Therefore, it is very important to design a model of gamification on physics learning context that can develop PPTs’ CT skills.

As a first step, the researcher sees that it is very important to mapping PPTs’ thinking style and CT skills on the study population. The thinking style can be classified into five categories namely; 1) Superior creative thinking (ScreT) style, 2) Creative thinking (CreT) style, 3) Balance thinking (BT) style, 4) Critical thinking (CriT) style and 5) Superior critical thinking (ScriT) style. By knowing the PPTs’ thinking style, we can easily to identifying the strengths and weaknesses of PPTs’ thinking [26].

2. Method

This is research a survey research focused to describe the profile of PPTs’ thinking style and CT skills. The survey involved 46 PPTs (M = 5, F = 41, average age = 19.7 years old) of the fifth semester who are enrolled in waves and optics courses at one of the universities in Ternate city. The data were collected through the test that consist of the thinking style test and the test of CT skills. The instrument to investigate PPTs’ thinking styles using the Yanpiaw Creative-Critical Styles Test that consist of 34 items (33 multiple choice questions and 1 essay question). PPTs’ thinking style was interpreted on the YCreative-Criticals Scoring indicator [26, 27]. The instrument of CT skills was designed base on Ennis framework of CT in the form of multiple choice questions related to the topic of interference and diffraction. The data of CT skills were analyzed by using quantitative descriptive analysis technique.
3. Result and discussion
The result of data analysis shows that the profile of PPTs’ thinking style can be shown in Table 1. Most of the PPTs in the study population have a critical thinking (CriT) style, and no one has a superior creative thinking (SCreT) style.

| Thinking Style | f  | Percentage (%) |
|----------------|----|----------------|
| SCreT          | 0  | 0              |
| CreT           | 2  | 4              |
| BT             | 6  | 13             |
| CriT           | 36 | 78             |
| SCriT          | 2  | 4              |
| Total          | 46 | 100            |

The PPTs’ CT skills on topic interference and diffraction can be shown in Figure 1.

A = focusing on a question, B = analyzing arguments, C = asking and answering questions of clarification and challenge, D = judging the credibility of a source, E = observing and judging observations report, F = deducting and judging deductions, G = inducing and judging inductions, H = making and judging value judgment, I = defining terms and judging definitions, J = identifying assumptions, K = deciding on an actions, L = interacting with others.

Figure 1. Profile of PPTs’ CT skills.

The first CT skills indicator is elementary clarification consisting of three sub-indicators; 1) focusing on a question, 2) analyzing arguments and 3) asking and answering questions of clarifications and challenge. For the 1st sub-indicator, PPTs are required to identify or formulate criteria for judging possible answers regarding the properties of light. In the 1st sub-indicator, the skills of PPTs with CreT style can be categorized as very high (100%), BT style as low (33%), CriT style as low (25%) and SCriT style as very low (0%). For the 2nd sub-indicator, PPTs are required to seeing similarities and differences between light and sound waves. In the 2nd sub-indicator, the skills of PPTs with CreT style can be categorized as very high (100%), BT style as medium (50%), CriT style as medium (56%) and SCriT style as medium (50%). For the 3rd sub-indicators, PPTs are asked to name the examples and non examples of everyday phenomena related to thin-film interference. In the 3rd sub-indicator, the skills of PPTs with CreT style can be categorized as medium (50%), BT style as low (33%), CriT style as low (22%) and SCriT style as very low (0%).
The second CT skills indicator is basic support consisting of two sub-indicators; 4) judging the credibility of a source and 5) observing and judging observations report. For the 4th sub-indicator, PPTs are required to give a reason why color red is the most strongly deviated than the other colors on the diffraction grating. In the 4th sub-indicator, the skills of PPTs with CreT style can be categorized as very high (100%), BT style as medium (50%), Crit style as low (31%) and ScriT style as medium (50%). For the 5th sub-indicator, PPTs are required to record generally desirable in double-slit experiment that aimed to determining the value of the slit separation. In the 5th sub-indicator, the skills of PPTs with CreT style can be categorized as very high (100%), BT style as high (67%), Crit style as high (56%) and ScriT style as medium (50%).

The third CT skills indicator is Inference consisting of three sub-indicators; 6) deducting and judging deductions, 7) inducing and judging inductions and 8) making and judging value judgment. For the 6th sub-indicator, PPTs are required to interpret the correct statements related to Young's double-slit experiment using yellow light. In the 6th sub-indicator, the skills of PPTs with CreT style can be categorized as very high (100%), BT style as high (67%), Crit style as medium (56%) and ScriT style as very high (100%). For the 7th sub-indicator, PPTs are required to make generalizations based on graphs showing the relationship between the slit separation and the distance of two bright fringes on the screen. In the 7th sub-indicator, the skills of PPTs with CreT style can be categorized as medium (50%), BT style as low (33%), Crit style as very low (11%) and ScriT style as medium (50%). For the 8th sub-indicator, PPTs are required to apply the principle of double-slit interference and single-slit diffraction to determine the wavelength of light. In the 8th sub-indicator, the skills of PPTs with CreT style can be categorized as high (67%), BT style as high (61%), Crit style as low (39%) and ScriT style as low (33%).

The fourth CT skills indicator is advanced clarification consisting of two sub-indicators; 9) defining terms and judging definitions; three dimensions and 10) identifying assumptions. For the 9th sub-indicator, PPTs are asked to define the term and consider the operational definition of Young's experiment. Based on the definitions, what will be happened to the distance of the bright fringes on the screen if the distance of two slots is doubled. In the 9th sub-indicator, the skills of PPTs with CreT style can be categorized as very high (100%), BT style as low (33%), Crit style as medium (53%) and ScriT style as very low (0%). For the 10th sub-indicator, PPTs are asked to identify assumptions for providing arguments whether at a certain point on the screen there is constructive or destructive interference. In the 10th sub-indicator, the skills of PPTs with CreT, BT and Crit style can be categorized as very low (0%), Crit style as very low (6%).

The fifth CT skills indicators is strategy and tactics that consists of two sub-indicators; 11) deciding on actions and 12) interacting with others. For the 11th sub-indicator, PPTs are required to formulate alternative solutions to enlarge the distance between two consecutive bright fringes on the screen. In the 11th sub-indicator, the skills of PPTs with CreT style can be categorized as medium (50%), BT style as very low (0%), Crit style as very low (3%) and ScriT style as very low (0%). For the 12th sub-indicator, PPTs are required to develop and respond toward erroneous concepts related to the result of Young's experiment. In the 12th sub-indicator, the skills of PPTs with CreT and BT style can be categorized as very low (0%), Crit style as very low (6%) and ScriT style as medium (50%).

Generally PPTs’ CT skills with CreT style are categorized as high (68%), BT style as low (36%), Crit and ScriT style as low (32%). It is shows that the learning activities that were implemented are only effective for developing PPTs’ CT skills with CreT style, but less in empowering PPTs’ CT skills with BT, Crit and ScriT style. Previous research has shown that there is a significant correlation between the number of flaws students defined about an argument and their scores from CT [28], and the CT style was positively correlated with the ability to pay attention [29]. The map of PPTs’ thinking styles and CT skills will be used as a reference in developing a model of gamification in the physics learning context.
4. Conclusion

The profile of PPTs’ CT skills for the group of superior critical, critical and balance thinking styles can be categorized is low, while for the group of creative thinking style can be categorized as high. This is show that it is very important to design a model of waves and optics course that can be develop PPTs’ CT skills with different kinds of thinking styles.

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References

[1] Presseisen B Z 1985 Thinking Skills: Meanings and Models. In A. L. Costa (ed.), Developing Minds pp. 43-48 (Alexandria, VA: Association for Supervision and Curriculum Development)

[2] Binkley M, Erstad O, Herman J, Raizen S, Ripley M, Miller-Ricci M and Rumble M 2012 Defining twenty-first century skills In Assessment and teaching of 21st century skills pp.17-66 (Dordrecht: Springer)

[3] Yüksel G and Alci B 2012 International Online Journal of Educational Sciences 4 (1)

[4] Pierce C E, Gassman S L and Huffman J T 2013 European Journal of Engineering Education 38 (3) 281-299

[5] Zhou Q, Huang Q and Tian H 2013 Creative Education 4 (12) 40

[6] Ennis R H 1985 Educational leadership 43 (2) 44-48

[7] Facione P A 2000 Informal logic 20 (1)

[8] Facione P 1990 Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction (The Delphi Report).

[9] Cottrell S 2005 Critical thinking skills (Basingstoke: Palgrave Macmillan)

[10] Gunawan G and Liliasari L 2012 Cakrawala Pendidikan (2)

[11] Putra P D A and Sudarti S 2015 Jurnal Kependidikan: Penelitian Inovasi Pembelajaran, 45 (1)

[12] Nugraha M G and Kirana K H 2015 in Prosiding Seminar Nasional Fisika (e-Journal) 4

[13] Gunawan G, Harjono A and Sutrio S 2015 Jurnal Pendidikan Fisika dan Teknologi 1 (1) 9-14

[14] Thohir M A, Wasis W and Sugimin W 2017 Jurnal Pendidikan Pendidikan Sains (Journal Research of Science Education) 1 (2) 62-67

[15] Herayanti L, Habibi H 2017 Jurnal Pendidikan Fisika dan Teknologi 1 (1) 61-66

[16] Saprudin S, Liliasari L and Prihatmanto A S 2017 Journal of Physics: Conference Series 895 (1) p. 012109

[17] Burkey D D, Anastasio M D D and Suress A 2013 Proceedings of 2013 Annual Conference and Exposition of the American Society for Engineering Education 3950–3968

[18] O’Donovan S, Gain J and Marais P 2013 Proceedings of the South African Institute for Computer Scientists and Information Technologists Conference 242-251

[19] Barata G, Gama S, Jorge J and Gonçalves D 2017 Proceedings of the First International Conference on gameful design, research, and applications 10-17

[20] Gordon N, Brayshaw M and Grey S 2013 Innovation in Teaching and Learning in Information and Computer Sciences 12 (1) 27-38

[21] Bartel A and Hagel G 2014 Global Engineering Education Conference (EDUCON) 957-960

[22] Poondej C and Lerdpornkulrat T 2016 Australian Educational Computing 31 (2)

[23] Deterding S, Dixon D, Khaleed R and Nacke L 2011 Proceedings of the 15th international Academic MindTrek Conference: Envisioning Future Media Environments 9-15

[24] Deterding S 2012 Interactions 19 (4) 14-17
[25] Mulyana A, Hindersah H and Prihatmanto A S 2015 Proceeding of the 4th International Conference on Interactive Digital Media (ICIDM)
[26] Piaw C Y 2004 Creative and Critical Thinking Styles (Serdang: Universiti Putra Malaysia Press)
[27] Piaw C Y 2010 Procedia-Social and Behavioral Sciences 2 (2) 551-559
[28] Kadayifci H, Atasoy B and Akkus H 2012 Procedia-Social and Behavioral Sciences 47 802-806
[29] Piaw C Y 2014 Procedia-Social and Behavioral Sciences 116 4839-4843