Pre-Service Physics Teachers’ Concept Mastery and the Challenges of Game Development on Physics Learning

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Abstract. This study is a survey that aims to describe pre-service physics teachers’ concept mastery at a university in Ternate. Data were collected through test standard instrument for physics which used in the teacher certification program. Data were analyzed by using quantitative descriptive technique. Based on the results of data analysis, it was concluded that generally pre-service physics teachers’ concept mastery can be categorized on low category (25.4%). The map of concept mastery will be used as a reference to developing game design in the physics learning context for pre-service physics teachers.

1. Introduction
Along with the development of science and technology, the use of digital games has been widely designed to facilitate students in learning physics concepts both at university level [1, 2, 3], high school [2, 4, 5, 6], junior high school [7, 8, 9, 10, 11, 12, 13, 14], Elementary school [15, 16] and also kindergarten [17]. Researchers have defined the game as an immersive, voluntary and enjoyable activity in which a challenging goal is pursued according to agreed-upon rules [18]. In the context of e-learning, a game is defined as an online environment that involves a competitive activity with a challenge to achieve a goal, a set of rules and constraints, and a specific context. Game features vary dramatically, including games of chance, games based on motor skills (also called twitch games), and games of strategy. Games for learning are called instructional games or serious games [19]. Educational game is competitive rule-based activities involving one or more players with an expressed goal of performing or meeting a goal at a superior level (i.e., winning) either in relation to a previous performance level (one player game) or in relation to the performance levels of other players. Success in the activity requires use of subject matter in some way [20]. In other literature, games can be viewed as tools for learning [8, 10, 12, 17, 21, 22, 23], tools for evaluation [7, 9, 16, 24] and can also be viewed as learning environments [11, 15].

Researchers have shown that integration of educational theory or implementation of strategies, models, learning methods has been done to optimize the use of digital games in facilitating physics learning such as cooperative/ collaborative learning strategies [4, 7, 13, 23], 5E learning cycles model [5], assessment [7, 9, 16, 24], meta learning/ meta-cognition [10], cognitive-affective interaction model and flow theory [15], conceptual physics [14], explanation-based approaches [11, 22], locus of
control [1]. The results of papers review show that the use of digital games in physics learning can increasing student engagement [2, 9], enjoyment [24], motivation [13, 16, 22], student perceptions [2, 7, 13, 16], conceptual change [14], cognitive elaboration of physical concept [12], divergent thinking [15], problem solving [16], which are ultimately can improving learning outcomes [1, 3, 4, 5, 7, 8, 9, 10, 11, 13, 16, 22 ] and student awareness [5].

Based on the paper analyzed, generally the use of games on physics learning at the middle school is more than the other level. Though the game has great potential to be developed for example in the context of physics learning in universities especially for pre-service physics teachers. As a first step, the researcher sees that it is very important to mapping pre-service physics teachers’ concept mastery on the study population so that it can be used as a reference to identify characteristics of materials which were the weak achievement and to plan developing game design in the context of physics learning for pre-service physics teachers.

2. Method
This research is a survey that was focused to describe pre-service physics teachers’ concept mastery at one of university in Ternate city. The survey involved 60 seventh semester students at one of the universities in Ternate city. The sample of the study was taken with consideration of the adequacy in taking the course of physics education. Data were collected through test standard instrument for physics which is used in the teacher certification program. The test instrument consists of multiple choice questions. Data analysis technique was done by using quantitative descriptive analysis technique.

3. Result and Discussion
The result of data analysis shows that the profile of pre-service physics teachers’ concept mastery can be categorized as low (25.4%) as shown in figure 1.

![Figure 1. Profile of pre-service physics teachers’ concept mastery](image)

A: physics and measurement, B: motion in one dimension, C: motion in two dimensions, D: the laws of motion, E: static equilibrium and elasticity, F: universal gravitation, G: fluid mechanics, H: sound waves, I: superposition and standing waves, J: electromagnetic waves, K: electric fields, L: current and resistance, M: direct current circuits, N: magnetic fields, O: alternating current circuits, P: image formation, Q: interference of light waves, R: diffraction patterns and polarization, S: heat and the first law of thermodynamics, T: heat engines, entropy, and the second law of thermodynamics, U: modern physics

In the physics and measurement material, the concept mastery of pre-service physics teachers was categorized as low (32%). Physics and measurement material is a material that describes the standards
of length, mass, and time, matter and model building, density and atomic mass, dimensional analysis, conversion of units, estimates and order-of-magnitude calculations, significant figures. Based on the test analysis, we found that physics teacher candidate students are still weak on indicators mentioning on length measurement results with vernier calipers & micrometer screw gauge, uses the rule of significant figure in calculating area or volume of an object based on vernier calipers measurement.

On the topic of motion in one dimension, the concept mastery of pre-service physics teacher was categorized as low (27%). In the population, we can identified the lack of concept mastery such as for indicator determines the average velocity, speed and acceleration of a moving object, describes the motion of an object based on the graph of \( x = f(t), \) \( v = f(t) \) and \( a = f(t) \). Students also have difficulty in solving physics problems related to determining the time and place where both people meet if the distance, speed and initial time are known. While on the topic of motion in two dimensions, the concept mastery of pre-service physics teacher was categorized as medium (47%). One of the lack of concept mastery is the indicator determines characteristics of projectile motion. If we look at the content of matter, these two topics involve quantities of physics to describe the motion of an object such as position, distance, displacement, velocity, speed, acceleration which were the basic for next physics material achievement. This topic is closely related to the phenomenon that can be found in everyday life. On the other hand, to understand this material requires a mathematical understanding.

Pre-service physics teachers’ concept mastery on the topic of the laws of motion can be categorized as low (40%). The lack of concept mastery was identified in the indicator on determining the effect of force to moving objects with certain speed and time. In the topic of static equilibrium and elasticity, Pre-service physics teachers’ concept mastery was categorized as low (25%). Pre-service physics teacher have difficulty on indicators of determining appropriate experimental design to investigate one of the factors affecting the magnitude of constant of the spring.

Pre-service physics teachers’ concept mastery on the topic universal gravity can be categorized as very low (12%). The force of gravity is an abstract concept, related to the interaction of one object with another object such as interaction on microscopic objects that can’t be seen also between objects with macroscopic size that can’t be presented in the class for example interaction between the sun and the planet or interaction between objects in the universe. In addition to understanding the force of gravity required understanding of mathematics. One of the weak concept mastery is the indicator determines speed of the satellite by applying the concept of gravity and centrifugal force.

Pre-service physics teachers’ concept mastery on the topic fluid mechanics can be categorized as low (34%). Fluid mechanics is one of the physics topics that the application of the concept commonly was found in everyday life. However, not all application concepts can be presented directly into the class for students to observe [25]. Pre-service physics teachers’ concept mastery on the topic fluid mechanics can be categorized as low (34%). Topics of fluid mechanics, is one of the topics that the application of the concept commonly was found in everyday life. In the population, the lack of concepts mastery was identified in indicator describes the graph of the relationship between the magnitude of the buoyant force and height, determine altitude from air pressure data or conversely.

The oscillations and mechanical waves in this survey are represented by topics of sound waves, superposition and standing waves, electromagnetic waves. Pre-service physics teachers’ concept mastery can be categorized as low with the percentage of 28% on the topic of sound waves, 33% on the topic of superposition and standing waves and 32% on topic of electromagnetic waves. In the population, the lack of concepts mastery was identified in indicator determining the magnitude of wavelength and the speed of waves based on a wave equation, identifying the properties of electromagnetic waves, and determining frequency which was detected by an observer based on the Doppler effect.

Pre-service physics teachers’ concept mastery on materials of electricity and magnetism can be categorized as low. Generally these materials contains abstract concepts, involving students in complex physical phenomena, requiring observation and interacting with three-dimensional phenomena, mentally difficult to transform 2D objects into 3D objects [8]. In addition, the application of concept on this material is very closely related to everyday life. In the population, the lack of concepts mastery was identified in indicator mentioning the result of voltmeter and ammeter measurement, determining the required resistance of an immersion heater that increases the
temperature of water heated for a certain time while operating at certain potential differences, calculating the power delivered to the lamp which were connected to a certain voltage, determining the distance of a charge from the other charge if we known the resultant of the electric force is zero, determining the ratio of the magnitude of two charges at the point which the electric field is zero, and determining the number of primary or secondary windings in the step-up transformer.

The image formation topic is part of the geometrical optics. While the topic of interference of light waves, diffraction patterns and polarization is part of physical optics. On this topic, generally pre-service physics teachers’ concept mastery was categorized as low. Mastery of concept on physical optics is the lowest achievement. The results of concept analysis show that the concept on this material was an abstract concept. This is supported by a number of studies showing that many students usually experience difficulty when conceptualizing abstract concepts in this material [26, 27]. In the population, the lack of concepts was identified in indicator determining the distance of the ocular lens should be shifted so that the eye can be maximum magnification based on the observed object with a microscope, applying the concept of interference, diffraction and polarization in solving physics problems.

Pre-service physics teachers’ concept mastery on thermodynamic materials can be categorized as low. In the population, the lack of concepts was identified in the indicators determining the rate of energy transfer on the event of conduction, determining the ratio of heat which necessary transferred to both types of objects with mass, specific heat and a certain temperature changes, calculating the energy transfer during phase change, using the concept of Carnot cycle to solve physics problems.

Pre-service physics teachers’ concept mastery on modern physics materials can be categorized as low. In the population, the lack of concepts was identified in the indicators determine the photon energy with an certain wavelength and frequency, determining the wavelength for an electron using De Broglie hypothesis, interpretation the graphic of intensity and wavelength on blackbody radiation, identification of characteristics, advantages and limitations of various atomic models, determining the number of protons, neutrons and electrons of atoms and ions, predicting the behavior of alpha, beta, and gamma rays in an electric or magnetic field, determining radioactive half-life of an substance. These findings are reinforced by Gunawan’s (2013) research which shows that students have difficulty in understanding the concepts in modern physics because generally this material contains abstract concepts so that need to be visualized [28].

On the several papers that have been studied, it has been shown that digital game has become an effective way of teaching physics concepts such as Newtonian dynamics [11, 13, 14, 22, 23, 29], Newton’s playground [9], energy [7], electrostatics [4, 8], electrical energy [5], electromagnetic [3] and optics [2, 10]. However, generally the use of digital games in physics learning is mostly done at junior high school and high school. To be successful in studying concept of physics on the populations, it is very important to design learning activities that can organize and condition the learning situation so that more interesting, challenging, fun, can be improving student engagement in concept exploration activities, learning concepts that can’t be practiced in the classroom, providing interaction experience with invisible and multidimensional objects, reinforcement of concepts, evaluating the concepts and provide for learning experiences related to the applications of concept. On the other hand, when teaching physics concepts, developing critical thinking and creative thinking becomes one of the challenges to planning further research. Games have the potential to be developed in the context of physics learning for pre-service physics teachers.

4. Conclusion

Based on the results of data analysis, it can be concluded that generally the profile of pre-service physics teachers’ concept mastery was categorized as low (25.4%). The map of concept mastery can be used as a reference in developing the design of learning activities that can organize and condition the learning situation that is immersive, interesting, challenging, fun and improving student engagement in physics learning. On the other hand, developing critical thinking and creative thinking are important skills that must be possessed by pre-service physics teachers.
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