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The 4th International Seminar on Science Education

Bandung, 30 October 2010

"Curriculum Development of Science Education in 21st Century"

Science Education Program
School of Postgraduate Studies
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Foreword of Chair of Science Education Program

The fourth International Seminar of Science Education is conducted to fulfill annual agenda of the School of Graduate Studies, Indonesia University of Education.

The seminar theme "Curriculum Development of Science Education in the 21st Century" is chosen emerge from many problems of science education in Indonesia. One of them is the overstuffed condition of science curriculum that affected from rapid development of information in this era. Besides, there are challenges of Indonesian people in facing against global competition. To win the competition they have to think critically. Therefore many massages have to cover by science curriculum caused it overloaded and difficult to be implemented.

We are not able to overcome the problem ourselves. We need input of information and experience from many researchers all over the world. Therefore this seminar hoped to be an exchange experience to solve the problem and lead to the discovery of science curriculum to enhance Indonesian science education quality.

I would like to express my special gratitude to Prof Dr Bruce Waldrip from Monash University, Australia; Prof Dr Russell Tytler from Deakin University, Australia; and Dr. Benny H.W.Yung from The University of Hongkong; who are specially come here to be key note speakers. Thank you for sharing the result of your latest result with us.

Finally I would like to thank to the committee who have been working hard to prepare the seminar and publish the proceedings. Last but not least thank you for all speakers and participants of your contribution today.

Bandung, 31 October 2010
Chair of Science Education Program
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Prof.Dr.Liliasari,M.Pd

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Science Education

Multiple Representations Skills and Its Influenced toward Students' Critical Thinking Disposition using a Virtual Laboratory Activity

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Abstract

The aim of this study is to explore students' multiple representation skills and critical thinking disposition when supported by a peer virtual laboratory activity. The subjects were pre-service physics students that were engaged in Quantum Physics learning situation based on multiple representation approach using IFSO framework. Three virtual laboratory activity related to photoelectric effect, Bohr's atom model, and Schrodinger equation application were given to the students in the treatment. The learning activities including virtual experiment, peer discussion and generating own multiple representations based on response improvement facilitated by the designed virtual laboratory learning environment. The findings of this study are that students' multiple representation skills are the keys to successful on critical thinking disposition. Students with high exploration ability can take better advantage from peer interactions and teacher guidance to generate more diversified representations modes ideas and analogies using virtual laboratory activity. In contrast, students with low exploration ability would have serious difficulty in representation skills. We conclude that exploration ability in virtual laboratory is a crucial factor that affects student's multiple representation skills. The study suggests that lecturers could design minds-on and hands-on activities supported by virtual laboratory activity to improve students' generated own multiple representation skills for enhancing critical thinking disposition.

Key Words : Representation Skills, Critical Thinking Disposition, Virtual laboratory

Background

The concern for teaching thinking skills is penetrating the education program everywhere in the world. All levels of society agree that thinking skills are crucial for one to remain relevant and proficient in this fast-paced and competitive world. In the era of massive information and technology explosion as such, there is an urgent need for pupils to learn in 'thinking schools', where teachers emphasize skilful thinking. The learning of thinking skills will be even more meaningful when it is reinforced in the lessons taught, with curriculum content as its context. When thinking skills are infused and weaved into the lesson instruction, students are able to gain a deeper understanding of the content they are learning, resulting in meaningful and transferable knowledge. (Lang, 2006).

Quantum physics has required many of the deepest minds in physics, so it is known as " a big challenge for thinking" that it is a difficult subject for students to learn. Similar to any topic in physics, quantum physics presents many of its own unique challenges that conspire to make it extraordinarily difficult and frustrating for most students to build mental models. It is counterintuitive and surprising to find that the microscopic world does not behave at all the way we would expect, as the intuitions we have built up from interacting with our daily environment do not hold up. Because most of the phenomena students study in quantum physics cannot be observed directly, it is often difficult to construct mental models by which to visualize such elusive phenomena. It is also mathematically challenging, involving lengthy calculations to analyze the simplest phenomena, with most realworld phenomena falling outside the realm of our ability to calculate. Finally, at least in the form it is often taught, quantum physics is disconnected from everyday life, focusing on simplified abstract models at worst, and phenomena with which we have no direct experience at best (S.B, Mc Kagan et al, 2009)

Quantum physics concepts can be built on a classical base theory, using many classical concepts and so can be rich in representations. If student understanding is weak in these areas, the learning of quantum physics may still be difficult (Bao and Redish, 2002). Although quantum physics is very representational rich but almost certain that traditional teaching ignores these richness. Student ability to build different kinds of physics representations for quantum physics can help them understand and use key physics concepts. Therefore, quantum physics lecture based on multiple representation is an alternative way to enhance students' understanding of quantum physics concepts.

Much previous research has shown that the use of multiple forms of representation in teaching concepts in physical science has great potential benefits, and yet poses significant challenges to students and instructors. Facility in the use of more than one representation deepens a students' understanding, but specific learning difficulties arise in the use of diverse representational modes (Meltzer, 2005). By "representational mode " we mean any of the widely diverse forms in which physical concepts may be served, understood and communicated.

Educators and researchers now widely agree that the discipline of science should be understood historically as the development and integration of multi-modal discourses (Kress et al. 2001; Lemke 2004), where different modes serve different needs in relation to reasoning and recording scientific inquiry. In this way, mathematical, verbal and graphic modes have been used individually and in coordinated ways to represent the knowledge claims of science discourse, with more recent technology-mediated representations of science consistent with, rather than a deviation from, this evolution of science as a discipline. By implication, students need to learn about the multi-modal nature of the representations entailed in scientific inquiry, and the different modes in which the same concepts in science can be represented as part of students' general development of science literacy (Waldrip et al, 2010)

Multimodality refers to the integration in science discourse of different modes to represent scientific reasoning and findings (Waldrip, et al, 2006;2010). The same concept is re-represented through different forms or "multiple representations" in verbal, numerical, visual, or actional modes. A focus on multimodal thinking and representation encourages students to coordinate their different representations of scientific knowledge. Ainsworth (1999) posited that learner engagement with representations could support learning in three ways. These are (a) when the new representation complements past understanding by confirming past knowledge, (b) the new representation constrains interpretation by limiting the learner focus on key conceptual features, (c) the different representations enable learners to identify an underlying concept or abstraction across modes or within the same mode of representation.

There is growing recognition in science educatin research of the key importance of understanding and conceptually integrating different representational forms in learning science and learning how to think and act scientifically (Ainsworth, 1999; Waldrip et al, 2010). These researchers argue that to learn science effectively students must understand different representations of science concepts and processes and be able to translate these into one another, as well as understand their coordinated use in representing scientific knowledge. While various classifications of these modes have been proposed, there is broad general agreement that these forms, for the purposes of learning science in secondary school, include such categories as verbal, graphic, mathematical, pictorial, simulations, and kinesthetic or embodied understandings or representations of the same concept or process. There is consensus in the literature that students need to develop an understanding of diverse modes, rather than be dependent on particular modes for specific topics, if they are to develop a strong understanding of how to interpret and represent science concepts and processes. There is also agreement that these modes of representation have different strengths and weaknesses in terms of precision, clarity, and associative meaning.

Learning fundamental ideas in quantum physics requires that the learner construct mental models of the system to be understood integrated dynamic representations that support argumentation, explanation and prediction. Visualizations facilitate this construction. However construction is not enough. Learning fundamental ideas in quantum physics requires that the learner coordinate multiple mental models. There are several kinds of mappings that can be used to accomplish this (Johnson et.al, 2001)

The use of computer simulations in learning environmental are promising tools that have been shown to be effective in helping students learn many topics in physics, especially in quantum physics (Rebello and Zolmann, 1999; Roblee et al, 1999; Ainsworth and Labeke, V.N, 2004). Because of the added problems of visualizing and building an intuition for the abstract concepts and principles of quantum physics, the power of simulations to provide interaction, visualization, and context has the potential to be even more helpful in this subject than in other physics topics. Many teacher/lecturers and researchers have developed computer simulations to assist students in learning quantum physics(S.B,. M.C Kagan et al, 2009).While many of these simulations may be useful for providing visual models of quantum phenomena, research on their user interface and effectiveness for learning has been limited. Many of the user interfaces or representations of physics are not consistent with research on user-interface design and how students learn, potentially limiting their effectiveness. The Physics Education Technology (PhET) Project creates research-based interactive computer simulations for teaching and learning physics and makes them freely available from the PhET web-site (http://phet.colorado.edu). The simulations are animated, interactive, and game like environments where students learn through exploration. We emphasize the connections between real-life phenomena and the underlying science, and seek to make the visual and conceptual models of expert physicists accessible to students. We have attempted to address the problem of student learning of quantum physics by developing PhET simulations in this subject using our research-based design principles, and conducting research on their effectiveness in various contexts (Mc. Kagan, S.B. et.al, 2009)
As noted by Johnson et.al (2001) that knowing a fundamental idea in science is not merely being able to repeat its standard verbal formulation, or to solve a canonical set of textbook problems. Verbal formulations and problem-solving skills can be acquired without understanding. Instead, cognitive and educational researchers have converged on the hypothesis that understanding an idea requires that the learner construct an internal representation, often referred to as a mental model, of the type of system for which that idea is relevant. A mental model is an integrated, dynamic representation that allows the learner to simulate the relevant system in the mind's eye. Mental models support argumentation, especially counterfactual reasoning, explanation and prediction. Educational materials abound with visualizations.

However, recognizing the power of advanced visualizations to support the construction of mental models does not specify which visualizations are most useful for particular topics, especially quantum physics concepts.

Method

The study followed a mixed methods approach entailing collection and analysis of quantitative and qualitative data (Creswell & Clark, 2007). This paper will draw on data from the quantitative step into a mix-method research of the role of multi representation in learning quantum physics concepts in a sequential embedded mixed method design with embedded experimental model will be used in overall study to cover the richness of the study.

A quasi-experimental, pre-post test design with students in quantum physics course class of pre-service physics teacher students was used for this study. The study will explore the effects of two synthesis tasks across three physics units under the overarching theme of quantum theory i.e photoelectric effect, Bohr's Atom Model, and Schrodinger Equation. The study was designed around two distinct stages. In the first stage, to address experimental group, we used multiple representation approach in teaching and learning processes. The second stage was to address control group students which used direct instructional teaching and learning model.

Discussion and Implication

Simulations are powerful tools for helping students visualize electrons, photons, atoms, wave interference, and other quantum phenomena that they cannot observe directly. While students can conduct experiments on topics such as the photoelectric effect and double slit interference in many physics labs, there is much going on inside these experiments that they cannot observe (S.B,. Mc Kagan, 2008). *Photoelectric Effect* simulation (Fig. 1) allows students to watch electrons travel between the plates, helping them to build a model of why the current increases when you increase the intensity (they can see that more electrons leave the plate) but does not increase when you increase the voltage (they can see that the electrons travel faster between the plates but the number of electrons stays the same).

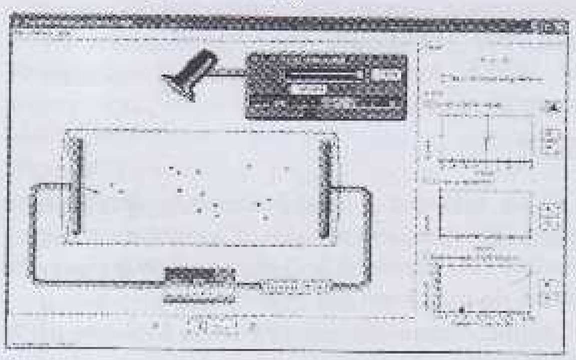

Figure 1. Photoelectric Effect simulation from PhET (available from http://www.phet.colorado.edu/quantum)

In learning process of photoelectric effect which embedded arguments with multiple representations, students try to design a virtual experiment using simulation from PhET (see fig 2). In virtual laboratory students conducted group's investigation about relationship between current and voltage as intensity function in photoelectric experiment. Furthermore student can conduct experiment about relationship between retarding potential effect and photon frequency. Figure 2 show the result student's plot stopping potential v.s frequency using MS Excel.

Beside, in virtual laboratory activity, students try to make their arguments with embedded multiple representation modes for promoting deeper understanding concept.

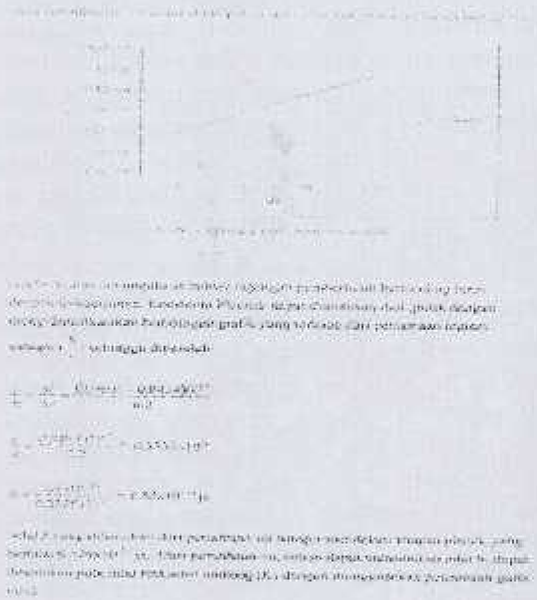

Figure 2. Students' investigation in virtual laboratory for Photoelectric Effect

Ainsworth (2006,) noted that students needed to know how science representations encode information, including interpretive procedures, or 'operators'. They also needed to know how to construct an appropriate representation, in terms of its fit with the conventions of science discourse, including brevity, compactness, absence of ambiguity, and structural coherence, or systematicity. According to diSessa (2004), "students start with a rich pool of representational competence" based on their past experiences with interpreting visual texts, and are 'strikingly good at ... designing representations". He considered therefore that "rich and engaging classroom activities are relatively easy to foster " that are highly motivating for learners.The results of that study supported my research results. From student activity in learning quantum physics concept (examples in photoelectric effect and Bohr's model atom), students tried to generate their own written text analogy representation that could be seen below.

Figure 3. Students' representation about Photoelectric Effect using an analogy

Furthermore, atomic models are an important part of physics instruction at many different levels. Atomic models are an important part of physics instructional many different levels. The study of atoms is a rich content area, providing a solid basis for understanding everything from the fundamental building blocks of nature to the basis of modern technology. The structure of atoms is both beautiful and useful. Furthermore, atomic models provide a good context for teaching scientific reasoning skills such as model building and making inferences from observations. The history of atomic models over the last century provides an exciting detective story in which students can be led through a complex web of reasoning about how new models are built and old models are discarded, based on a few simple observations.(S.B Mc Kagan et al, 2008). In learning process we also present interactive computer simulations designed to help students build models of the atom more effectively, especially for Bohr's atom model (see figure 4).

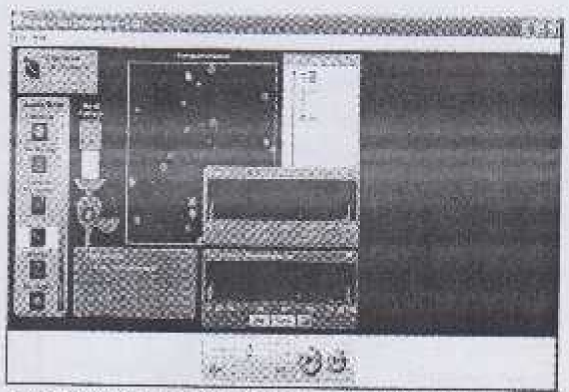

Figure 4. Virtual experiment of Hydrogens' atom simulation (available from http://www.phet.colorado.edu/quantum)

Carolan, Prain, & Waldrip (2008) stated that students can also translate ideas from one type of representation to another, thus shifting their mode of reasoning as they re-organize their understanding to take into account visual, spatial and verbal aspects of topics. As students develop a representation as a claim, the teacher and/or students can direct attention to inconsistencies of interpretation, and thus provide further opportunities for reasoning about causal factors. Constructing representations can also enable students to keep track of their progress in problem-solving in a topic, can refine and clarify first impressions, and can promote the pleasure of recognition of understanding when students see that their representation makes a clear and convincing case.

Figure 5 showed verbal (written text) mode representation that generated by students.
This example suggests that the students could (a) gain crucial insights into the reasoning of students as they construct and justify representations, (b) provide targeted feedback on the adequacy of the claims implied in these representations, and (c) guide the students' reasoning as well as in a timely fashion explain the purpose of particular conventions in scientific representations, especially understanding "atom modeling" and its role in covering abstract concept. There is increasing recognition that developing students' capacities to interpret and construct these complex science texts poses significant cognitive and pedagogical challenges that it could promote students' scientific literacy (Waldrip, Prain, and Carolan, 2006).

Figure 5. Students' written representation on Bohr's atom model related to other model

Moreover, to assist students understanding of Schrodinger Equation and its application, we have served *Quantum Tunneling and Wave Packets* simulation. Many of the quantum simulations take advantage of the power of computers to quickly do complex calculations without exposing the user to the details. Thus, students can explore quantum tunneling and quantum wave interference qualitatively and focus on understanding the concepts without getting involved in the difficulty of math. This has the potential to radically transform the way quantum mechanics is taught because it allows the instructor to focus on the problems that are most important for students to understand rather than on the problems that are easiest to calculate (S.B Mc. Kagan et al, 2008).

Using *Quantum Tunneling and Wave Packets* (Fig. 6) in learning process allows us to begin our instruction on tunneling with wave packets, so that students can visualize an electron as a slightly but-not-completely delocalized object that approaches a barrier, interacts with it, and then partially reflects and partially transmits. This is not only much easier to visualize and understand than a wave packet spread over infinite space interacting with a barrier for all time, but also more physically accurate.

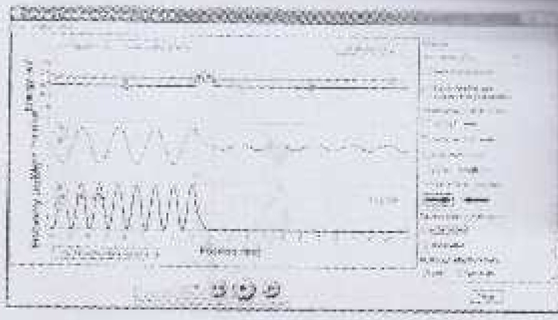

Figure 6. *Quantum Tunneling and Wave Packets* simulation(available from http://www.phet.colorado.edu/quantum)

In learning environmental students were given opportunity to predict wave function before using simulation through analyzing Schrodinger equation for potential barrier phenomena, especially for square barrier. Figure 7 showed how students predicted wave function in the potential barrier system.

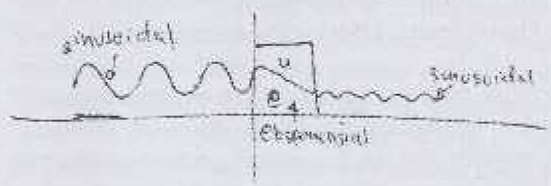

Figure 7. students' sketch wave function in different Region

According to final examination of Critical Thinking Disposition, as figure 8 to 10 displays, the effect of multiple representation-based instruction of photoelectric effect concept, Bohr's atom model, and Schrodinger Equation gave more gain meta-learning known as critical thinking disposition integrated with their concepts. Based on data analysis could be conclude that all N-gain score for overall indicators of critical thinking disposition for Experimental Group (EG) were higher than that for Control Group (CG).

For all N-gain score of critical thinking disposition photoelectric concept-integrated (CTDPE) for CG were categorized in low level (g=0 - 0.3), whereas almost all N-gain score of CTDPE for EG were categorized in medium level (g= 0.3 - 0.7), except for open mindedness (OM=0.75) which has N-gain score was high level categorized (> 0.7). Beside for inquisitiveness (INQ) indicator for EG has N-gain score in low level (0.20) (see fig.8)

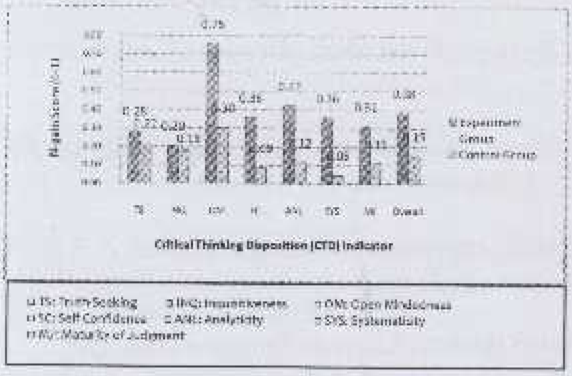

Figure 8. N-gain of CTDPE for EG and CG

Furthermore, figure 9 showed that all N-gain score for overall indicators of critical thinking disposition Bohr's atom model concept-integrated (CTDBA) for EG were higher than that for CG.

Almost all N-gain score of CTDBA for CG were categorized in low level (g=0 - 0.3), whereas all N-gain score of CTDBA for EG were categorized in

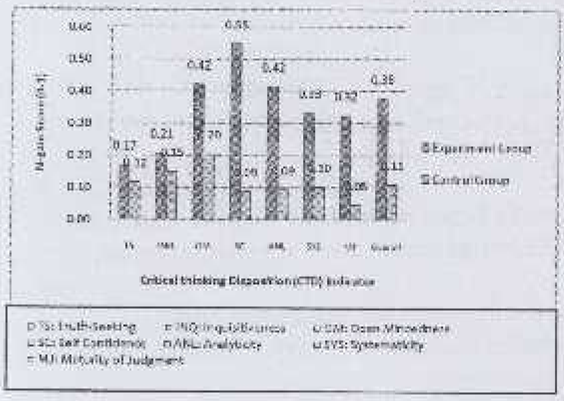

Figure 12. N-gain of CTDBA for EG and CG

medium level (g= 0.3 - 0.7), except both truth seeking (TS=0.17) and inquisitiveness (INQ=0.20) indicators which were categorized in low level.

According to final examination of Critical Thinking Disposition of Schrodinger Equation Concept (CTDSE), figure 10 showed that the effect of multiple representation-based instruction of Schrodinger equation concept gave more gain meta-learning known as critical thinking than that of the direct instruction with limitation of representation modes. It could be seen that all N-gain score for overall indicators of CTDSE for EG were higher than that for CG. For all N-gain score of CTDSE for CG were categorized in low level (g=0 - 0.3), whereas almost all N-gain score of GSSSE for EG were categorized in medium level (g= 0.3 - 0.7), except for truth seeking (TS=0.21) and inquisitiveness (INQ=0.18) indicators which have N-gain score was low level categorized (< 0.7).

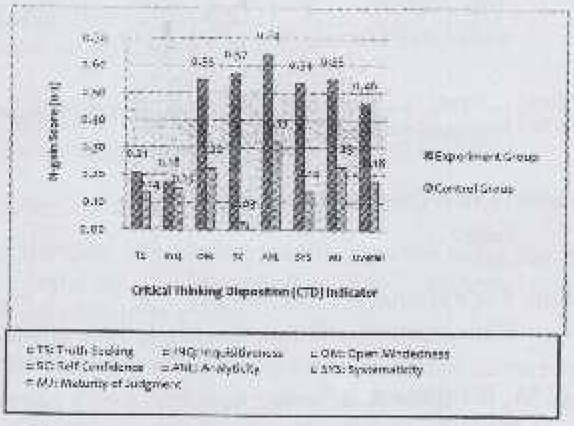

Figure 10. N-Gain Score of CTDSE for EG and CG

As we could be seen that some CTD indicators did not increase in the treatment. From the literature we know that disposition toward critical thinking appears to be stable over a period of years, but yet there is a space for significant growth (Rimiene, 2002). Our investigation has corroborated this view. Some dispositions developed significantly as a result of our programme, while some remained unchanged significantly. Truth-seeking scores did not increase and were the lowest of all the dispositions measure. In many studies with which we are familiar, truth-seeking mean scores are also worrisome indicators of weakness in this important aspect of the CT disposition. However, statistically significant increases in truth-seeking can occur over a period of years (Facione, Facione, and Giancarlo, 2000). Truth-seeking can be considered as a personality dimension and as such may be slow to develop or change.

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