CHAPTER 5
CONCLUSION AND IMPLICATION

5.1 Conclusion

Based on the overall results of the study could be concluded that:

a) Student are more likely to use existing representation from a domain resource than to generate their own representation, use mathematical representation in learning and physics problem solving, and their representations (SR) are strongly dependent on teacher/lecturer's representation (TR)

b) Students' preconception in quantum physics is strongly influenced by classical physics conceptions and students' misconceptions in several quantum physics concepts have been repaired through multiple representation-based instructions.

c) Multiple Representations-based instructions has been developed by using *IF-SO* framework approach appropriately with specific quantum physics concepts such as Photoelectric Effect, Bohr's Atom Model, and Schrodinger Equations.

d) This research study has documented that multiple representations-based instruction versus the conventional instruction did make a significant influence on the quantum physics mastery, generic science skills, and critical thinking disposition of pre-service physics teacher students.

e) Multiple representations-based instructions enhanced students' re-representation skills significantly.

f) The result of semi-structured interviews indicated that the experimental group students used variety of representations in learning quantum physics and were capable of using the most appropriate one for the given quantum physics concept problems.

g) Most of the students mentioned that the multiple representations-based instructions were appropriate to enhance understanding and quantum physics concepts mastery. Therefore they had some inspirations how to create an innovative teaching and learning physics instructions.

5.2 Implication of Study

5.2.1 Implications for teaching practice

Effectiveness physics instruction needs more than lecturing. It requires active involvement of the students in physics learning process. Multiple representations-based instructions meets this need in physics classroom.

In quantum physics courses, lecturers are responsible for designing constructivist situations and concrete connections for students so that scaffolding of knowledge can be achieved. Lectures should also encourage students to think about connections between multiple representations. This study carried out based on general reasoning from physician that the lack of physical concepts understanding comes from not being able to make connections between different representational modes of mathematical concepts and processes. Besides, quantum physics requires an adequate use of models and a deep conceptual understanding of the underlying abstract ideas. Overall, it had been observed that hands-on activities, computer visualization programs and constructivist pedagogy enable students to build conceptual changes which explain their observations.

In interviews students agreed the idea that they like to be engaged in all kinds of representations for solving quantum physics problems. Therefore, teachers should emphasize applications of multiple representations. In a very simple way, establishing relationships between representational modes can be conducted in part of a daily lesson by making students to think about any situation that represents a physical object. Besides, allowing students to create their own representations, such as analogy makes them more creative and flexible in physics situation. However, students should be given an opportunity that they can use representations that they invent or create variety of modes representation in learning physics.

Moreover, using multiple representations in teaching of quantum physics should be emphasized in pre-service physics teacher education programs. In pre-service physics teachers' education programs, there are instructional design in which the ways of instructing quantum physics are introduced. These courses can be modified considering the need for multiple representations in modern physics in order to make pre-service students familiar with the concept of multiple representations and remark the importance of this concept in physics teaching. By this way, the pre-service teachers would be capable of preparing their lesson plans including multiple representations in physics. In addition to instructional design, the multiple representations of concepts should be emphasized in physics courses of pre-service teachers as well. Particularly, the use of computer technology and laboratory apparatus can provide promising opportunities for the different representations of quantum physics concepts. In this sense, pre-service teachers would better see the benefits of multiple representations-based instructions while they are promoting and shaping teacher knowledge base such as Content knowledge (CK), Pedagogical Content Knowledge (PCK), and Pedagogical Knowledge (PK).

One further implication can be suggested for the school physics textbooks and other teaching materials. The physics textbooks for elementary until high schools students are lacking of connections among representational modes of mathematical concepts. Almost of physics textbooks only served to include the symbolic and mathematical modes of representations. It will be beneficial to include other representational modes in addition to the symbolic and mathematical modes. Textbooks should not consider these representational modes as separated topics, but should give a clear attention to the translations and relationships among them.

The usage of multiple representations should also be valued in the new physics curriculum due to its various advantages. Multiple representations based instruction should be implemented in various topic in physics curriculum, such as mechanics, waves, energy, electricity, and heat and thermodynamics. The involvement of multiple representations in physics curriculum will accordingly make teachers or lecturers give more importance to multiple representations in instruction.

5.2.2 Theoretical Implications

This study confirmed Ainsworth functions of Multiple External Representations (MERs) theory. The theory of multiple representations based on the premise that students learn the physics concepts and build new concepts making a meaningful relationship between the previous ones, only by dealing with variety of representational modes of the concepts, and communicating with these modes of representations. Though it was not the intentional to look for evidence to support the theories considering multiple representations, it is consistent with the learning experiences in the current study.

The current study does not agree with the idea that students might be confused when they are provided with more than one representation. If translations among representation modes are established, they can develop deeper understanding and more likely to use different representation modes for solving one problem, instead of being lost in variety of representations. This view is supported by the statement in many previous studies. As noted by some researchers that a conceptual analysis of existing multiple representational learning environments suggests there are three main functions that multiple external representations (MERs) serve in learning situations - to complement, constrain and construct. The first function is to use representations that contain complementary information or support complementary cognitive processes. In the second, one representation is used to constrain possible (miss) interpretations in the use of another. Finally, MERs can be used to encourage learners to construct a deeper understanding of a situation.

This study emerged others new theoretical views about functions of MERs that suggested a great contribution of existing multiple representational learning strategy to promote Generic Science Skills, high order thinking especially for critical thinking disposition, and knowledge based teacher.

5.3 Recommendations for Further Research

Generally, having known what students gathered from multiple representation-based instructions in this research study suggests some ideas for further research studies in physics classrooms. In this manner, future research can focus on teachers representation skills and teaching strategies in physics based on multiple representation and other science subject matter such as biology and chemistry courses. All of the data for this study was collected from students. Future research could combine data from students and their teachers/lecturers, because teachers/lecturers have also impact on shaping students' representation preferences. What teaching strategies and representation types are used within physics classrooms by teachers and how those representations are conceptualized by the students seems to be worthwhile to study. Some students during the interviews claimed that they prefer to use mathematical mode of representation to solve quantum physics problems because it seems to them more mathematical and they were taught with more emphasis on this kind of representation during learning physics as well as since senior high school. Such study examining the reasons of that belief and the degree of teacher effects on that belief would be a deeper level of investigation after this study.

Multiple representation-based instructions can totally be replicated in small groups since as students were dealing with representational modes; they need to discuss their thought with others. Small group works would give them this opportunity. Besides, the replications of this study can be conducted with a random sample so that the results could be generalized over a wider population.

Further studies could also be conducted beyond the physics courses. Multiple representation-based approach can be implemented to every topic in quantum physics concepts. Photoelectric Effect, Bohr's Atom Model, and Schrodinger Equation were chosen for this study, however it is strongly recommended to use this instructional design in further related topics such as quantum mechanics, solid state physics, and nuclear physics. Especially for freshmen of the pre-service physics students who will cover Fundamental Physics course, the multiple representations-based instruction is strongly recommended to implement for developing knowledge based teacher early.

This study was carried out in a twelve week period. Further research can apply multiple representations-based instructions approach for longer periods.

Possible studies in this area could look more closely on gender issues in representation preferences. It was beyond the aim of this study to investigate the gender differences in students` preferences regarding to representational modes. However, it would be interesting to find out evidence like girls are more likely to prefer a certain representations than boys. Furthermore, this instructional approach might be applied on elementary, junior or senior high school students.