CHAPTER 3
METHODOLOGY

This chapter presents the procedures for the study. It includes descriptions of the overall research design, the population and the sample, the description of the variables, the data collection instruments, the design of the instruction, the pilot study of the instruction, the treatment procedure and data analyses approach used to address each research.

3.1 Research Paradigm and Design

Recent, the issues of what instructional approaches should be used in physics classes have not been solved yet. No matter which instructional approach is used, the primary goal of physics instruction should be to help students in forming conceptual understanding. Kohl & Finkelstein (2007) suggest that if the teachers enrich their physics classrooms by using multiple representations, the students can more efficiently make connections between the meaning of physics concepts and the way of representing them, therefore they simply “go for the meaning, beware of the syntax” which results in conceptual understanding.

From a global and historical perspective, physics, as an academic subject is extremely successful in a number of areas, providing, for instance, rather generic methods in analyzing and solving complex problems (Euler, 2004). Thereby, physics instruction should build generic science skills for supplying scientific literacy and increasing the number of students in physics-related careers. Generic Science Skills, which include direct and indirect observation, sense of scale, using symbolic language, developing need for logical self-consistency, developing logical inference, understanding causality, developing mathematical modeling, and developing concepts, are considered essential for undergraduate physics students. Since many of these skills are an indispensable part of the lifelong learning process, some even consider them more valuable than subject matter (Brotosiswojo, 2001).

The concern for teaching thinking skills is penetrating the education system 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 (Lang, 2006). Physics is considered abstract, difficult, boring, unattractive, not very meaningful to students and detached from every day life. Many students who begin their physics lesson with a certain level of enthusiasm and eagerness soon change their attitude and consider the subject uninteresting and even develop aversions (Euler, 2004). However, preparing pre-service physics teachers student to teach thinking skills requires more than the generic attitude, skills, and knowledge components for effective teaching. This dispositional component is closely related to the affective dimension of a particular thinking skill, i.e., the willingness and inclination to think in a particular way (Lang, 2006).

Therefore, developing enrichment instructional strategy based on multiple representations, especially on quantum physics, will be clearly an effect toward critical thinking disposition and scientific generic skills to pre-service physics teacher student. The diagram representation for the framework of reasoning of this research could be seen in figure 3.1

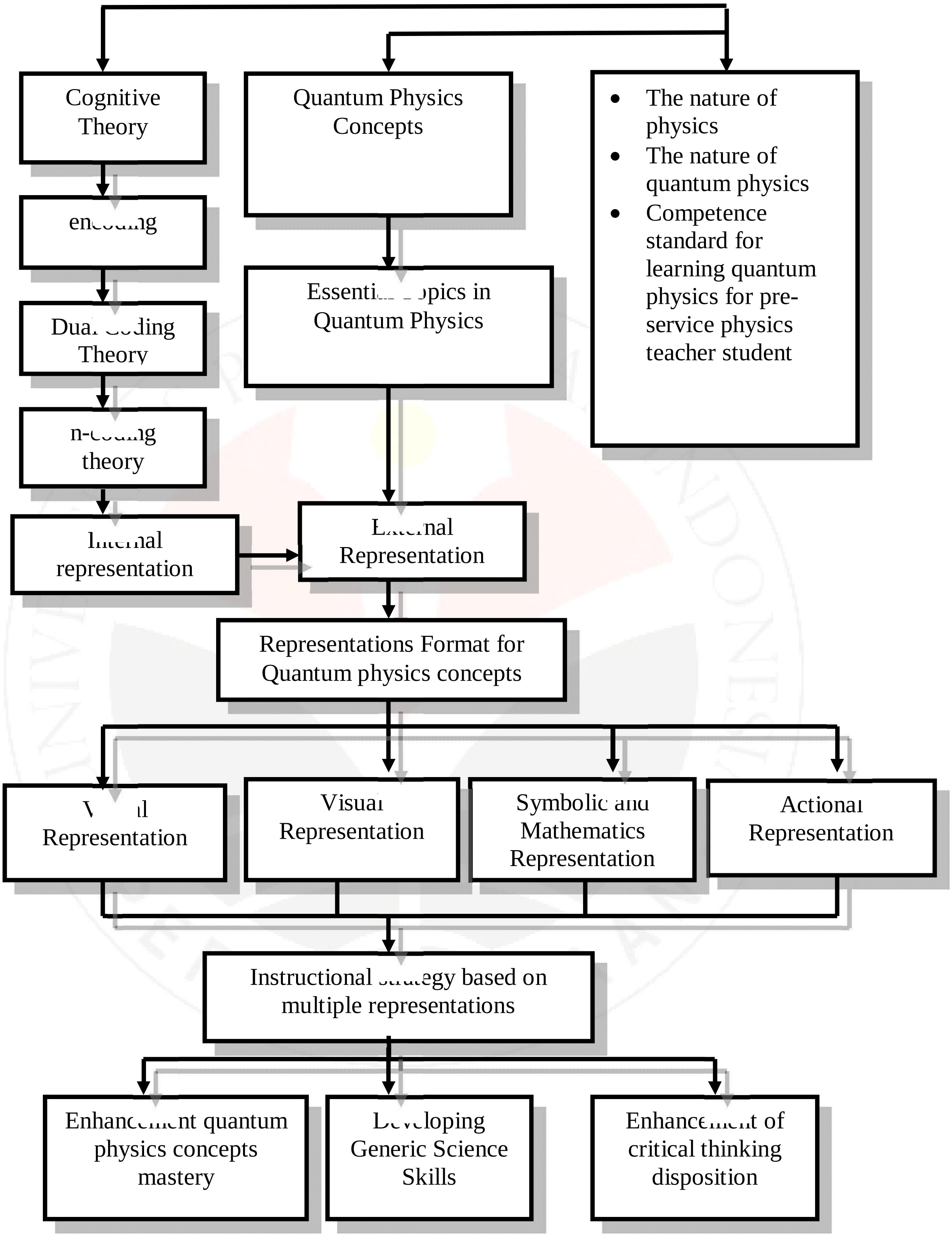


Figure 3.1 Reasoning Diagram of Framework of the Research

The research was conducted using the mixed method approach. *Mixed methods research* is formally defined here as *the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study* (Teddlie & Tashakkori, 2009). Philosophically, it is the "third wave" or third research movement, a movement that moves past the paradigm wars by offering a logical and practical alternative. Philosophically, mixed research makes use of the pragmatic method and system. Its logic of inquiry includes the use of induction (or discovery of patterns), deduction (testing of theories and hypotheses), and abduction (uncovering and relying on the best of a set of explanations for understanding one's results). Mixed methods research also is an attempt to legitimate the use of multiple approaches in answering research questions, rather than restricting or constraining researchers' choices (i.e., it rejects dogmatism). It is an expansive and creative form of research, not a limiting form of research. It is inclusive, pluralistic, and complementary, and it suggests that researchers take an eclectic approach to method selection and the thinking about and conduct of research (Johnson & Onwuegbuzie, 2004).

In this research mixed method approach was designed in learning quantum physics with a rich environment based on multimodal representation and its influence toward concept achievement, critical thinking disposition, and developing growth of generic science skills in pre-service physics teacher. A sequential embedded mixed method design with embedded experimental model has been used (see figure 3.2) (Creswell & Clark, 2007).

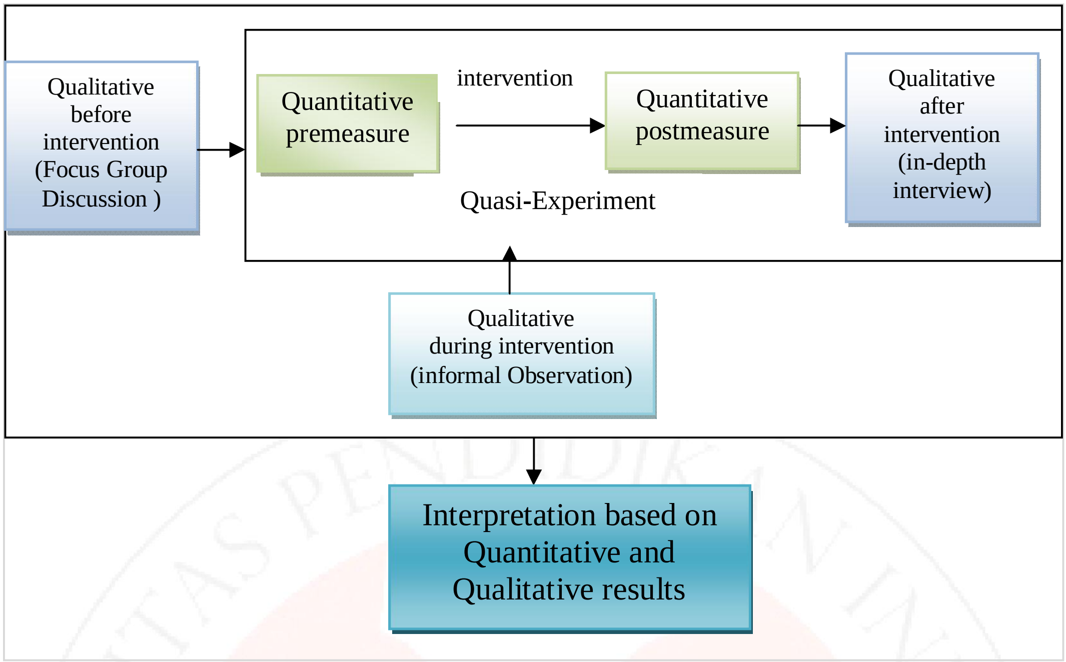


Figure 3.2 Sequential Embedded Research Design (Creswell & Clark, 2007)

The main purpose of this study was to create and test the effect of instructional design based on multiple representation for quantum physics concepts. The effect of treatment will be examined through a quasi-experimental research design since this study does not include the use of random assignment of participants to both experimental and control groups (Creswell & Clark, 2007; Borg, Borg & Gall, 2003; Creswell, 2008). This research design can be visualized as in Figure 3.3.

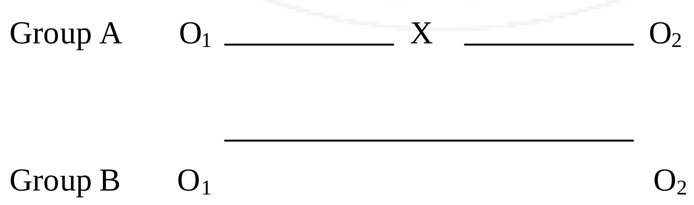


Figure 3.3 The visual representation of research design for the quantitative study

In Figure 3.3, the symbol of O_1 represented the scores obtained through the instruments that would be used as pretests. The experimental class is represented as Group A which experienced the treatment (X) that used instructional based on multiple representations, called experiment group (EG). The Group (B) received only traditional instruction and is represented as control group (CG). The symbols O_2 represent scores of the post administration test using the instruments on both experimental and control groups.

The secondary purpose will be to gather qualitative data. The first step will used structured interview through Focus Group Discussion (FGD) to investigate the representation preferences of the students before the unit of instruction, to examine the reasons of preferring certain kinds of representations, and to investigate skills of representation before the unit of instruction. Focus group discussions are ***a qualitative research technique used to gain an in-depth***, but not representative, understanding of the attitudes, beliefs and perceptions of a specific group of people in their own language. A focus group would be facilitated, open conversation, recorded and observed by a note taker. A facilitator asked questions that stimulate interaction among participants on subjects relevant to the evaluation. Each participant should have the opportunity to speak, ask questions of other participants and respond to the comments of others, including the facilitator. Generally, it is best to hold several focus groups on the same topic. The first few focus group sessions are often longer because the facilitator is getting all new information. Thereafter, the facilitator should be able to move quickly over points that have already been covered with previous groups if similar answers are emerging.

The number of focus group discussions have been conducted depends on the project needs and resources and whether different views from separate groups are still emerging. In general, at least two focus group discussions should be conducted among each specific target group. Each group consisted of 6-12 persons. The focus group was conducted between 75 to 90 minutes (Gruden, *et al.*, 2002).

In this study has been formed 5 groups, each group consist of 7-8 persons. The students that will be member of group are pre-service physics teachers who have taken quantum physics concept course.

The second qualitative step used informal observation during intervention of the class, and the last step used think aloud semi-structured interviews to know how the students use multiple representations when they encounter a quantum physics learning situation and students' perception and view about learning quantum physics based on multiple representations. In semi-structured interview engaged about 6 students. Two students from high level understanding of quantum physics concept mastery, two students from medium level, and two students from low level were engaged in the interview. In overall of design of the research was summarized in Table 3.1.

Table 3.1 Summary of research design

General Initial Teaching and Learning Design		
Proposed Strategy	Resources	Outcome
Focus group discussions (FGD)	Pre-service Physics teacher students	Development of a set of Treatment covering focus, attitude, content, learning and teaching based on Multiple representations.

Literature Review		
Proposed Strategy	*Resources*	*Outcome*
Review a wide selection of related research articles in science education, especially physics education research using multiple representation	Library databases, research articles	Clear understanding of the scope of related research
Identify Key Themes, Ideas and Concepts		
Proposed Strategy	*Resources*	*Outcome*
Enter the field with open and responsive research outlook	Lecturer within the Physics Education Program of Mathematics and Science Education Department	Adaptation of an appropriate research methodology
Collect and analyse data from a wide range of sources	Lecturers, students, researchers, examination scripts, lectures, tutorials, virtual laboratories	Adaptation of appropriate data collection and analysis tools
Identify key categories	Analysis software	Awareness of emerging concepts
Develop an Interview Based Research Instrument		
Proposed Strategy	*Resources*	*Outcome*
Progressively focus toward the initial research questions		Adaptation of appropriate data analysis tools
Isolate the key areas of interest and the key aspects of quantum physics concept learning based on multiple representation		Development of a set of interview questions

Conduct Interviews		
Proposed Strategy	*Resources*	*Outcome*
Interview students	6 Students	Development of a responsive interview protocol
Analyse interview data to identify themes		Categorization of responses
Investigate the Variation in Understanding of Key Quantum Physics Concepts		
Proposed Strategy	*Resources*	*Outcome*
Step back from the data and refocus on isolating a set of key concepts relating to the teaching and learning of quantum physics concept	Interview transcripts	Adaptation of appropriate research methodology and analysis tools. Mapping the variations in understanding
Link Results		
Proposed Strategy	*Resources*	*Outcome*
Analyse the results for trends and connections	Analysis software tools (using SPSS v 16)	Research findings

3.2 The Population and Sample of The Research

The target population of this study consists of all pre-service physics students from public University, Faculty of Education and Teacher Training, in Bandar Lampung, Lampung Province, Indonesia. The sample covered all student who administrated quantum physics concept course in 2009/2010 year academic that consist of 37 students. They were separated to experimental group that received instructional based on multiple representation and control group that received only conventional instructions. This class had a total population 37 of students. There were 19 students in experimental group and 18 students in control group.

3.3 The description of variables of study

In this study there were 5 variables that can be classified as dependent and independent variables. Table 3.2 presents a list of those variables.

Table 3.2 Classification of the variables

Variable Type	Name	Value type	Scale type
Dependent	Students' concepts mastery score on Photoelectric effect, Bohr's atom model, and Schrodinger equation.	continuous	interval
Dependent	Students' Generic Science Skills score which integrated photoelectric effect concepts, Bohr's atom model concepts, and Schrodinger equation concepts.	continuous	interval
Dependent	Students' Critical Thinking Disposition score which integrated photoelectric effect concepts, Bohr's atom model concepts, and Schrodinger equation concepts.	continuous	interval
Dependent	Re-representation Skill Inventory score	continuous	interval
Independent	Treatment	categorical	nominal

The first of the dependent variables is the students' conceptual mastery in quantum physics concepts scores. These scores were obtained from pre and post test of Quantum Physics Survey (QPS) which including Photoelectric Effect Concept score, Bohr's Atom Model Concept scores and Schrodinger's Equations Concept scores. The next one of dependent variables is the students' Generic Science Skills scores. These variables include Generic Science Skill-Integrated Photoelectric Effect Concept Score, Generic Science Skill Integrated Bohr's Atom Model Concept Score, and Generic Science Skill-Integrated Schrodinger's Equation Concept Score. The next one of dependent variables is the students'

Critical Thinking Disposition which include Critical Thinking Disposition-Integrated Photoelectric Effect Scores, Critical Thinking Disposition-Integrated Bohr's Atom Model Concept score, and Critical Thinking Disposition-Integrated Schrodinger Equation Concept scores. The last one of dependent variable is the students re-representation skill score.

The independent variables of this study is the treatment (Multiple representations-based instructions was experienced to experimental group and conventional instructions was experienced to control group) that considered as categorical variable.

3.4 Instruments

Two instruments were used in quantitative study for this research. There were Quantum Physics Survey (QPS) and Re-representation Skills Inventory (RSI). Quantum Physics Survey (QPS) contains 60 multiple choice items which consist of 20 items related to Photoelectric Effect Concepts, 20 items related to Bohr's Atom Model Concepts and 20 items related to Schrodinger's Equations Concepts. The QPS was used to measure students' quantum physics concept mastery achievement and integrated with this also generic science skills and critical thinking disposition (see appendix C). Whereas, the Re-representation Skills Inventory (RSI) is used to assess students' re-representation ability which it contained 9 essay items.

In addition to these instruments, for the qualitative step of the study, Focus Group Discussion guiding questions and interview task protocol (ITP) were used to collect more information and insight about both of the participants' pre-conception and understanding of using multiple representations in quantum concepts teaching and learning situation and physics problems solving.

3.4.1 Pilot Study of Students' Quantum Physics Concept Achievement

One of the instruments measuring students' quantum physics performance was the Quantum Physics Survey (QPS). To analyze students' answers more deeply and to explore their understanding and problem solving skills intensively, multiple choice type questions were used in QPS. QPS consists of 60 multiple choice items: 20 items related to photoelectric effect, 20 items related to Bohr's atom model, and 20 items related to Schrodinger's Equations. Almost all of the test items were developed by the researcher and several items were taken from the related literature. These instruments are presented in Appendix D.

A pilot study for this instrument was conducted with 38 pre-service physics students who passed quantum physics courses or sixth grade semester chosen from physics education program, department of mathematics and science education, at a public University in Lampung Province. The given time for completing the initial version of the QPS was 80 minutes in the pilot study. The minimum and maximum possible scores from the test items are 0 and 100 points, respectively. Internal consistency reliability estimate for the QPS was measured by *Cronbach* alpha using SPSS v.16 to be 0.784 for photoelectric effect concept, 0.799 for Bohr's atom model concepts, and 0.828 for Schrodinger's equation concepts respectively. A reliability coefficient of 0.70 or higher allows a norm-referenced test to be used with confidence. For internal validity and difficulty index of the instrument computed using SPSS v.16 could be seen in table 3.3 to table 3.5.

Table 3.3 Internal validity of instruments and Difficulty Indices of QPS related to photoelectric effect concept

Item	Pearson Correlation	Sig.(2-tailed)	Validity	Difficulty Index	Inferred
q1	0.413	0.010	sig.	0.63	Ok
q2	0.661	0.000	sig.	0.55	Ok
q3	0.406	0.012	sig.	0.53	Ok
q4	0.648	0.000	sig.	0.58	Ok
q5	0.477	0.002	sig.	0.47	Ok
q6	0.587	0.000	Sig.	0.55	Ok
q7	0.512	0.001	sig.	0.58	Ok
q8	0.537	0.001	Sig.	0.58	Ok
q9	0.425	0.008	sig.	0.58	Ok
q10	0.334	0.041	sig.	0.34	modified
q11	0.349	0.032	sig.	0.50	Ok
q12	0.550	0.000	sig.	0.47	Ok
q13	0.390	0.016	sig.	0.26	Ok
q14	0.512	0.001	sig.	0.58	Ok
q15	0.011	0.947	Not sig.	0.34	Replaced
q16	0.618	0.000	sig.	0.50	Ok
q17	0.437	0.006	sig.	0.37	Ok
q18	0.501	0.001	sig.	0.37	Ok
q19	0.063	0.708	Not sig.	0.34	Replaced
q20	0.376	0.020	sig.	0.26	Ok

*. Correlation is significant at the 0.05 level (2-tailed)

**.Criteria for Difficulty index : 0-0.3 difficult; 0.3-0.7 middle; 0.7-1.0 easy

Table 3.4 Internal validity of instruments and Difficulty Indices of QPS related to Bohr's atom model concepts

Item	Pearson Correlation	Sig.(2-tailed)	Validity	Difficulty Index	Inferred
q1	0.415	0.010	sig.	0.68	Ok
q2	0.516	0.001	sig.	0.79	Ok
q3	0.433	0.007	sig.	0.45	Ok
q4	0.253	0.216	sig.	0.45	modified
q5	0.533	0.001	sig.	0.47	Ok
q6	0.700	0.000	sig.	0.47	Ok
q7	0.479	0.002	sig.	0.42	Ok
q8	0.494	0.002	sig.	0.84	Ok
q9	0.388	0.016	sig.	0.63	Ok
q10	0.489	0.002	sig.	0.66	Ok
q11	0.747	0.000	sig.	0.53	Ok
q12	0.394	0.014	sig.	0.50	Ok
q13	0.346	0.033	sig.	0.42	Ok
q14	0.418	0.009	sig.	0.42	Ok
q15	0.176	0.289	Not sig.	0.42	Modified
q16	0.562	0.000	sig.	0.50	Ok
q17	0.373	0.01	sig.	0.45	Ok
q18	0.436	0.006	sig.	0.53	Ok
q19	0.466	0.003	sig.	0.39	Ok
q20	0.526	0.001	sig.	0.50	Ok
N	38				

*. Correlation is significant at the 0.05 level (2-tailed).

**.Criteria for Difficulty index : 0-0.3 difficult; 0.3-0.7 middle; 0.7-1.0 easy

Table 3.5 Internal validity of instruments and Difficulty Indices of QPS related to Schrodinger's equation concepts

Item	Pearson Correlation	Sig.(2-tailed)	Validity	Difficulty Index	Inferred
q1	0.552	0.000	sig.	0.68	Ok
q2	-0.094	0.576	Not sig.	0.26	Replaced
q3	0.788	0.000	sig.	0.55	Ok
q4	0.383	0.018	sig.	0.55	Ok
q5	0.513	0.001	sig.	0.71	Ok
q6	0.507	0.001	sig.	0.55	Ok
q7	0.665	0.000	sig.	0.63	Ok
q8	0.496	0.002	sig.	0.58	Ok
q9	0.338	0.038	sig.	0.61	Ok
q10	0.495	0.002	sig.	0.45	Ok
q11	0.822	0.000	sig.	0.55	Ok
q12	0.543	0.000	sig.	0.66	Ok
q13	0.439	0.006	sig.	0.71	Ok
q14	0.361	0.026	sig.	0.61	Ok
q15	0.608	0.000	sig.	0.55	Ok
q16	0.541	0.000	sig.	0.53	Ok
q17	0.417	0.009	sig.	0.55	Ok
q18	0.666	0.000	sig.	0.50	Ok
q19	0.642	0.000	sig.	0.53	Ok
q20	-0.059	0.725	Not sig.	0.47	Replaced
N	38				

*. Correlation is significant at the 0.05 level (2-tailed).

**.Criteria for Difficulty index : 0-0.3 difficult; 0.3-0.7 middle; 0.7-1.0 easy

For obtaining evidence about the face and content validity of this instrument, the QPS was checked by two experienced expert (lecturers) in terms of its format and content. They agreed on the appropriateness of the language, and the level of understanding the items refer to concept characteristics.

3.4.2 Pilot Study of Generic Science Skills (GSS)-Concepts Integrated

Internal consistency reliability estimate for the GSS was measured by *Cronbach* alpha using SPSS v.16 to be 0.806 for GSS-photoelectric concepts integrated, 0.841 for GSS-Bohr's atom model concepts integrated, and 0.852 GSS-Schrodinger's equation concepts integrated respectively. A reliability coefficient of 0.70 or higher allows a norm-referenced test to be used with confidence. Whereas, validity analyses using *Pearson* correlation showed that the instruments have significance internal validity.

3.4.3 Pilot Study of Critical Thinking Disposition (CTD)-Concepts Integrated

Internal consistency reliability estimate for the CTD was measured by *Cronbach* alpha using SPSS v.16 to be 0.739 for CTD-integrated photoelectric concepts, 0.709 for CTDI- Bohr's atom model concepts integrated, and 0.805 for CTD-Schrodinger's equation concepts integrated respectively. A reliability coefficient of 0.70 or higher allows a norm-referenced test to be used with confidence. Whereas, validity analyses using Pearson correlation showed that the instruments have significance internal validity.

3.4.4 Pilot Study of Re-representation Skills Inventory (RSI)

The re-representation skills inventory (RSI) was developed by the researcher for this particular study, which would address the last of forth research question that is to identify the representation competence of students. It consists of 9 questions (3 questions for Photoelectric concept, 3 question for Bohr's Atom Model concept, and 3 question for Schrodinger Equation concept) which students were given the problem and three different ways (Verbal, tabular/pictorial, and mathematical) of representing the problem. They were asked to choose difference of the representations to solve the given problem. The crucial point of this survey was that the students were required to translate representation mode the problems to other representation in solving the solutions of problems.

The pilot study of RSI was carried out with 38 pre-service physics student. Internal consistency reliability estimate for the RSI was measured by *Cronbach* alpha using SPSS v.16 to be 0.747. A reliability coefficient of 0.70 or higher allows a norm-referenced test to be used with confidence. Whereas, validity analyses using person correlation showed that the instruments have significance internal validity.

3.4.5 Focus Group Discussion Guiding Question and Interview Task Protocol (ITP)

Melzer (2005) stated that students` representational competence can be deduced by investigating their usage of representations in learning physics situations. Due to this reason, interviewing with students seemed to be the best method to understand the students` understanding in a multiple representation context. Focus short interview was conducted through Focus Group Discussion to explore students' physics representation preferences and quantum physics pre-conception before the unit quantum physics concept instruction based on multiple representation. Semi-structured interviews were conducted to obtain data on how students used different representational modes when they were solving quantum physics concept problem and to obtain deeper understanding about the possible reasons of their representation preferences.

In general, there were three types of questions, the aim of asking the first type of questions is to know about students' pre-conception and representation context in physics.

Four type of questions were aimed to obtain information about their use of multiple representations in quantum physics concept teaching and learning. Each question had one quantum physics concept context and needed generalization. The students were questioned on why they chose one type of representation over others both to engaged in learning and solve physics problem.

The interview process involved the purposeful sampling of 6 students from experimental group. Each interview lasted approximately 120 minutes. These interviews took place in the teacher's room in college at times that suited to students' schedules and all the interviews were audio taped with the permission of the student. During the interviews, there were some rules that the researcher must obey and situations that the researcher should provide for the participating students. First of all, the researcher informed the interview participants about the purpose and the content of the interview, and then she asked each of the participant's permission to record all the interview session by audio recorder. For facilitating understanding of students' thoughts, it is crucial that the participants feel comfortable and willing to give honest answers to the questions.

3.5 The design of Quantum Physics Concept Instruction based on Multiple Representation

The research has reformed an environment lecture of quantum physics concept course for pre-service physics teacher students by gradually changing both the content structures and the learning techniques implemented in lecture and homework based on multiple representations. Traditionally this course has been taught in a manner similar to the equivalent course for physics majors, focusing on mathematical solutions of abstract concept, including photoelectric concept, Bohr Atom model, and Schrodinger equation. Based on the *trialogue style using IF-SO frame work* in instructional design (figure 3.4), it was necessary determine that students in a reform-style quantum physics concept course are learning a broader set of representational performance than those in a more traditional course (Figure 3.5)

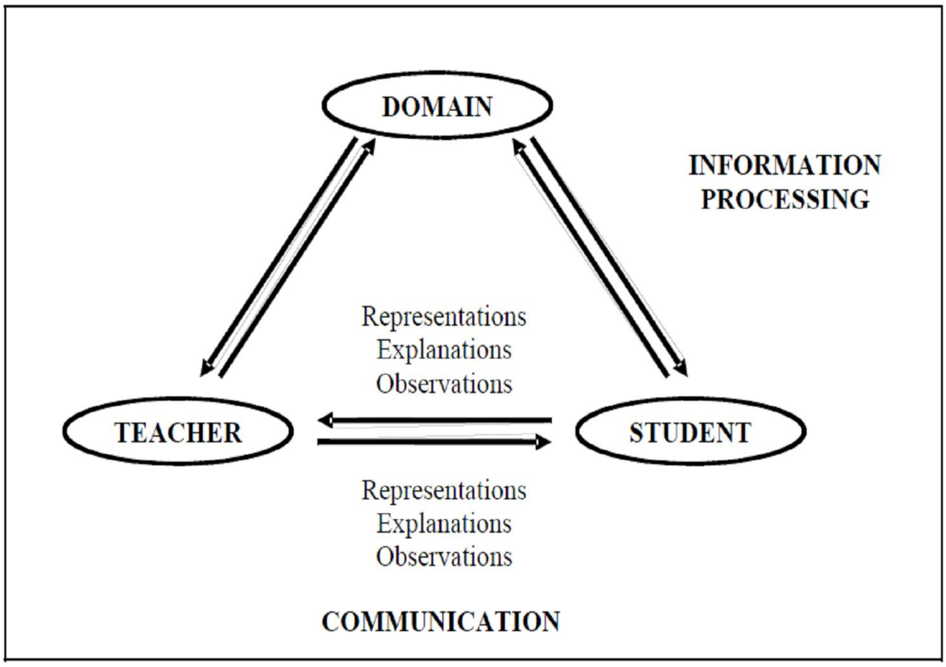


Figure 3.4 The *trialogue* style using IF-SO frame work

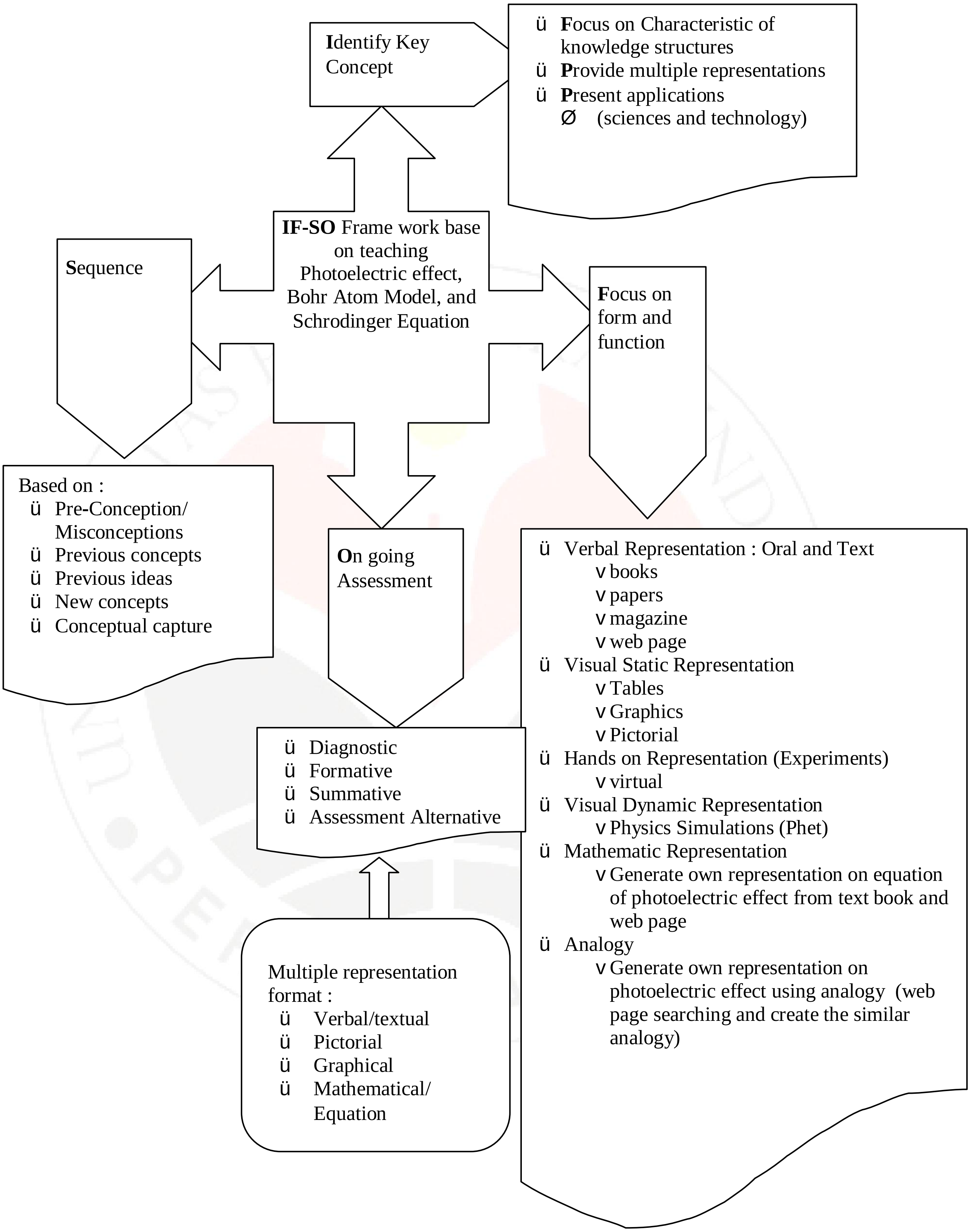


Figure 3.5 The characteristic of the instructional environmental design of a multiple representation based on IF-SO framework

In order to provide precise sequences this instructional environment design, we associated the idea of *conceptual change*, which assumes that learning is a substitution of a scientific concept for a misconception or previous ideas that the student already possessed. For this reason, we included this set of sequence of learning design and learning processes:

1) Evaluating of previous concepts
2) Determining goals of the learning and objectives in each level for knowing student's *conceptual capture* (diagnostic, formative and summative)
3) Selection of resources to help to the learner (texts, images, experiment, simulation, analogy etc)
4) Producing activities (virtual task, quizzes, essays, projects, and tests)
5) Developing interaction (collaborative work, peer works, with lecturers, web page and web blog)
6) Integral evaluation: diagnostic, formative and summative.

The second factor will contribute in learning design and learning process is *the change of representation* or multiple representations format in learning process; this factor is associated with the abstraction levels, like the figure 3.6. The student will passes through of an abstraction level to another one. Thus, with the multiple representation approach, we can create a constructivist-learning environment:

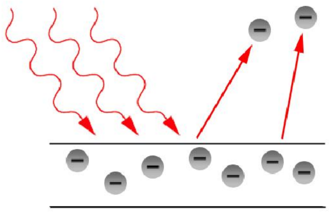
1) Provide different abstraction levels of certain physics concept, for example *photoelectric effect concept*, (physical, textual, pictorial, graphics and equations)

2) Work on the complexity of this microscopic phenomenon (investigation of interaction between electrons and photons using simulation and analogy)

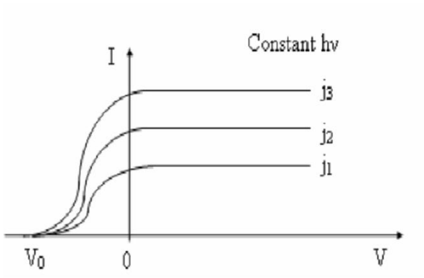
3) Contextualize activities (experiment using virtual laboratory)

4) Provide technological applications for photoelectric effect concept (weblog and web page activity)

5) Support collaborative work and interaction with peers and lecturer (including homework activity)



(a)

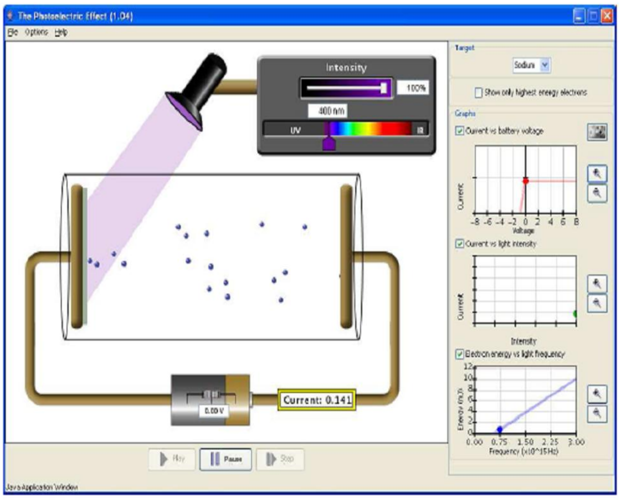


(b)

$$E_{\max} = h\upsilon - E_B \ ,$$

$$E_{\max} = eV_0 = \frac{1}{2}mv_{\max}^2$$

(c)



(d)

Figure 3.6 The multiple representation of same phenomenon for photoelectric effect ((a) pictorial (b) Graphical (c) mathematical/equation (d) simulation)

For details of how the students were engaged in during the treatment in this study: the experimental group was primarily given activities based on multiple representations. This approach presents and develops concepts through verbal (oral and writing), symbolic and equation, graphical, pictorial, tabular/bar , analogy and simulation. To illustrate, for understanding the concept of Einstein's equation for photoelectric effect was first introduced from a numerically intuitive approach in which tables were used to collect the data and refine them on activity sheet from virtual laboratory. Then a verbal representation was used to verbally complement what was the relationship among the numbers in the other modes of representation. Finally, a transition and generate own representation was made to the quantum physics concept using graph, analogy and simulation.

The usage of multiple representations varied for each activity presented in this treatment. For instance, for the topic of photoelectric effect, first the pictorial representation then the verbal representations were constructed. Student was given chance to generate their own representation modes, such as developing symbolic and equation from graph or data observation from virtual laboratory experiment through simulation physics. However, for conceptualizing the concept of Planck's constant from a graph, first, the mathematical and symbolic representation, and then the other representations including verbal and simulation were used.

The usage of multiple representations also varied for the activities. Even after the presented mathematic or equation representations were introduced to the students and conceptualized, the pictorial, verbal and graphical interpretations of these concepts were not ignored. Many times, students obtained answers in an mathematical form, they were asked to interpret them in different representational modes as well. For example, students were not only required to translate graphical representation to mathematical/equation but also vice versa. It was aimed to make students to understand that the final achieving point is not the mathematical/equation form; the translation from an algebraic type of representation to a graphical one was also appreciated. Activities were given to the students and they were responsible to deal with them.

There were daily or sometimes weekly activities by which students were provided opportunities to demonstrate how to manipulate of abstract symbol and equation, tables, graphs, verbal expressions, using simulation and analogy representations to fit well in one context. While implementing the treatment, first of all, the class was organized with respect to the activity requirements of that particular day. Then, the researcher or one of the students distributed the activity sheet, and if applicable necessary participative. The students were given some time to read and understand the activity. After that, the class discussed the activity and its requirements. Then the phase of dealing with the activity sheets was begun. When the students were on the given task, the researcher provided feedback to the students on their errors and questions. At last, students had a chance to demonstrate their approaches including multiple representations to deal with the activities. Their works were discussed with whole class. The errors, questions or unclear parts were taken into account by the researcher when she was making conclusion for the students. Table 3.6 showed the example of construct of the lesson.

Table 3.6 The construct of the lesson plan of experimental group

Learning Structure and outcomes	Student Activity	Lecturer Activity	Goal of Activity
Introduction : 15 minutes • Become aware that lesson will begin to start • Know what lesson will cover and what will happen during the lesson	Listen to explanation of lesson	• Open lesson • Distribute today's activity sheet • Explain the main idea of today's activity and promote some guide questions for understanding a topics	• Defining the problem • Observing • Forming the question • Articulating the expectation
Body (Main activities) : 125 Minutes • Understand the main concept of the lesson • Make all necessary translations among representations mode • Do the exercise physics problem solving	• Work in each group • Take notes • Fill activity sheet • Discuss the ideas to translate among representations mode with the other students • Group presentation : present the results representations mode is created	• Guide students when necessary	• Investigating the known • Carrying out the study • Communicating with others • Examining the result
Conclusion : 10 minutes • Recall and consolidates experiences	• Recall and share the main concept of the topic	• Review main points of lesson	• Reflecting on the finding

However, treatment in control group was given a conventional quantum physics based on direct instruction can be characterized by its emphasis on procedural skills and manipulating only symbolic/mathematical expressions. In control groups the teacher usually begin by providing the rules for operations for manipulating mathematical concepts. After providing students with this rule, the teacher demonstrated several examples that incorporated the rule. The same process was then repeated for the other rules and procedures. Throughout the lesson presentation the teacher asked for questions from the students and asked them to help for solving the equation. The students in control groups were responsible for listening to the teacher, taking notes from the whiteboard, and solving the questions that the teacher asked to them.

3.6 Data Analysis Procedure

In order to uncover the role of multiple representations-based instruction on pre-service physics teacher students' quantum physics performance, critical thinking disposition, and science generic skills, both quantitative and qualitative analyses of data proposed by the research questions will used. Onwuegbuzie and Teddlie (Johnson & Onwuegbuzie,2004) proposes seven-stage conceptualization of the mixed methods data analysis process. According to these authors, the seven data analysis stages are as follows: (a) data reduction, (b) data display, (c) data transformation, (d) data correlation, (e) data consolidation, (f) data comparison, and (g) data integration.

Data reduction involves reducing the dimensionality of the qualitative data (e.g., via exploratory thematic analysis, memoing) and quantitative data (e.g., via descriptive statistics, exploratory factor analysis, cluster analysis). *Data* *display*, involves describing pictorially the qualitative data (e.g., matrices, charts, graphs, networks, lists, rubrics, and Venn diagrams) and quantitative data (e.g., tables, graphs). This is followed (optionally) by the *data transformation* stage, wherein quantitative data are converted into narrative data that can be analyzed qualitatively and/or qualitative data are converted into numerical codes that can be represented statistically. *Data correlation* involves the quantitative data being correlated with the qualitized data or the qualitative data being correlated with the quantitized data. This is followed by *data consolidation*, wherein both quantitative and qualitative data are combined to create new or consolidated variables or data sets. The next stage, *data comparison* involves comparing data from the qualitative and quantitative data sources. *Data integration* characterizes the final stage, whereby both quantitative and qualitative data are integrated into either a coherent whole or two separate sets (i.e., qualitative and quantitative) of coherent wholes. The *legitimation* step involves assessing the trustworthiness of both the qualitative and quantitative data and subsequent interpretations. Figure 3.6 showed summary for step by step sequential data analyses for mixed method approach.

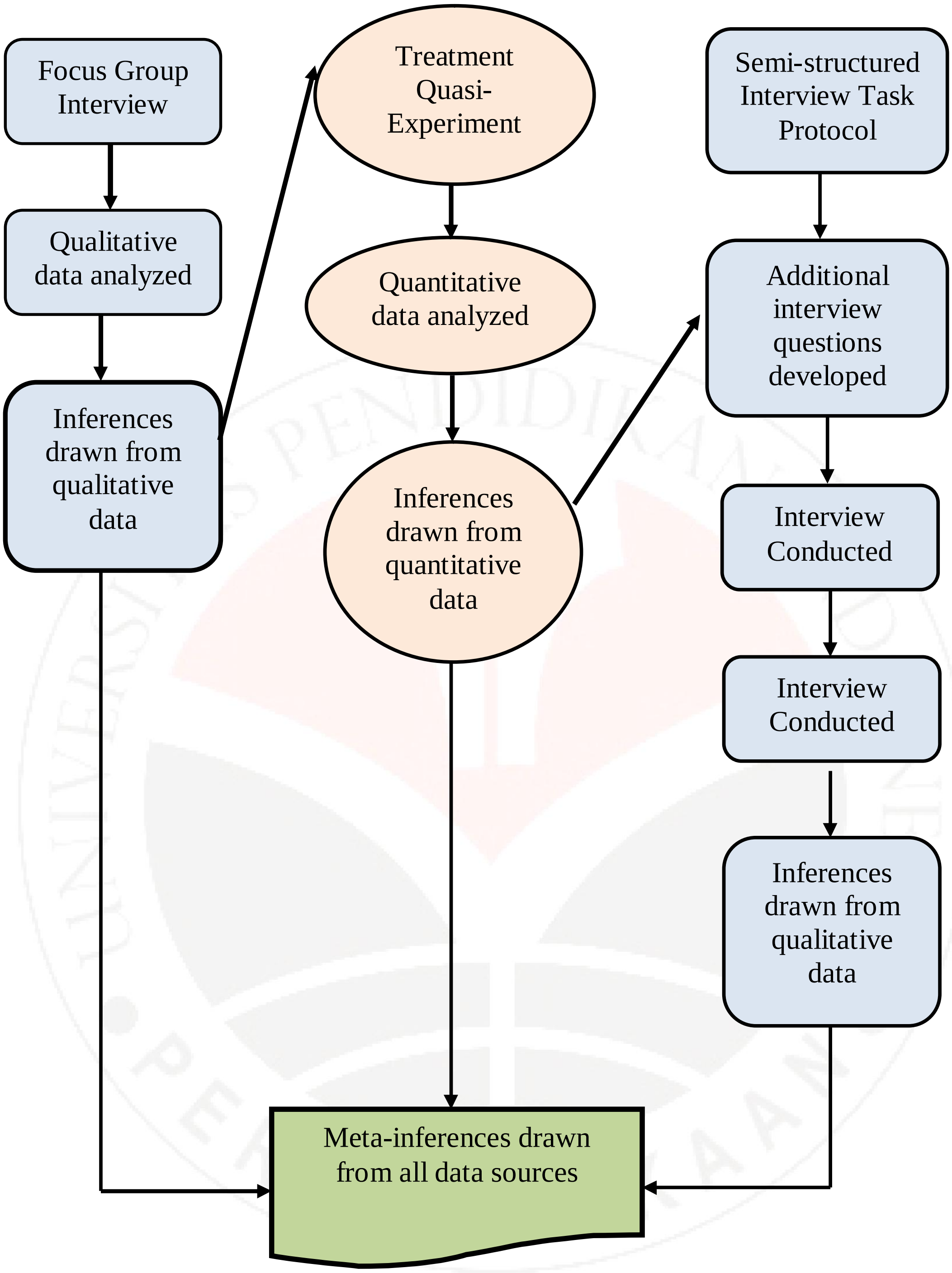


Figure 3.7 Sequential mixed method data analyses procedures

3.6.1 Quantitative Data Analyses

Quantitative data analyses will be classified as descriptive and inferential statistics. All the statistical analyses were carried out by using both Spread Sheet Excel and SPSS version 16. Data is initially examined to obtain descriptive statistics of the mean, median, mode, standard deviation, skewness, kurtosis, maximum and minimum values, and the describing graphs were presented in this part of statistics for experimental and controls groups involved in this study. To test the null hypothesis, the statistical technique of *Mann-Whitney U* Test (Minium, King, & Bear, 1993) will used for comparing the mean scores of control and experimental groups separately on the Quantum Physics Survey (QPS) and Re-representations Skills Inventory (RSI).

All quantitative data will used in term N-gain normalized score which could be gained from formula:

$$\mathrm{N-gain} = \frac{S_{post} - S_{pre}}{S_{\max} - S_{pre}} \quad \text{(Meltzer, 2002)}$$

3.6.2 Qualitative Data Analysis

The conceptual framework of the study guided the qualitative analyses of data obtained from the students' observation and interviews. The responses from participants will be transcribed and coded. The focus of the analyses is on how students use multiple representations in quantum physics, ways of the students' understandings of representational modes offered by the treatment and the reasons why the students make the choices that they do when they solving problems on pretests and posttests. The procedure data collection and analysis will use CDC EZ-TEXT 3.06 software.

All interviews were videotaped and then transcribed. When it finished transcribing the interviews, it will be used EZ-TEXT 3.06 to help analyze the transcriptions. I used EZ-TEXT 3.06 to create four categories to place students' responses. Then the categories is constructed based upon expert-like problem solving strategies. The different categories show different ways students use representations to help solve problems. The categories are: (a) Participants used representations to understand the problem/concept; (b) Participants used representations to help solve the problem; (c) Participants used representations to evaluate their work and or answers; (d) Participants used representations to check for the consistency of other representations.

The data was transcribed and coded all of the interviews' result, furthermore it was counted the number of comments a student made which fit into one of these categories. Then it was necessary to compare the number of responses students made in each of these categories with the level (high achieving, low achieving, or unique in characteristic) of the student. It also needed to compare any trends in the student's responses to a detailed analysis of the certain problem from the certain interview simultaneously. Furthermore, it also needed to revealed students' responses how they encountered learning strategy in the study.