CHAPTER I
INTRODUCTION

1.1 Background

Humans have always the curiousity about the world. Humans have been to observe the physical and biological environment carefully, look for any meaningful patterns and relations, make and use new tools to interact with nature, and build conceptual models to understand the world. The inquiring and imaginative human mind has responded to the wonder and awe of nature in different ways. This human endeavour is science . Science is the process of using observable facts to draw conclusions; of learning, inventing, and testing laws, hypotheses, and theories that accurately describe the relationships between observable phenomena; of improving the accuracy of such findings; and of communicating with others about such findings (Wenning, 2015), a method of learning about nature (Staver, 2007), both a process and product (Newton, 2008), expanding body of knowledge covering ever new domains of experience (*National council of Educational Research and Training*, 2006). Learning science is an active process. Students describe objects and events, ask questions, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others (*National Science Education Standards*, 1996).

The main goal of science teaching is help students understand the nature of science and how to use scientific inquiry ways (Tanriverdi & Demirbas, 2011). Education in science serves three purposes. First, it prepares students to study science at higher levels of education. Second, it prepares students to enter the workforce, pursue occupations, and take up careers. Third, it prepares them to become more scientifically literate citizens. The relative priority and alignment of these three purposes varies extensively across countries and cultures. Regardless of the setting, a sound education in science emphasizes that science is both a way of knowing and a body of knowledge; it also emphasizes integrating scientific inquiry with scientific knowledge (Staver, 2007). So, in teaching science, we build upon students' everyday knowledge of the world around them and augment this by providing carefully designed activities in which students observe or interact with real objects and materials. Teacher should be help students to develop an understanding of the natural world: what it contains, how it works, and how we can explain and predict its behaviour. These activities are usually carried out in the field, in teaching laboratories or earth science topics.

Physics is basic of science (The Academic Work Group, 2000). Laboratory work is essential in the study of Physics. In general, the purpose of these laboratory exercises is both to demonstrate some physical principle and to teach techniques of careful measurement (Loyd, 2008). Although laboratory work has often been separated from classroom work, research shows that experience and experiment are often more instructionally effective when flexibly integrated into the development of concepts. Scientific experimentation has powerful educational value by engaging students deeply in both the content and processes of science and by providing a practical perspective and cognitive connection to the theoretical materials presented in a classroom setting (Jona and Adsit, 2010).

The American Association of Physics Teachers (1997) sets the goals of Physics laboratory are engage each student in significant experiences with experimental processes, including some experience designing investigation, helping the student develop a broad array of basic skills and tools of experimental Physics and data analysis, helping students master basic Physics concepts, helping students understand the role of direct observation in Physics and to distinguish between inferences based on theory and the outcomes of experiments, and helping students develop collaborative learning skills that are vital to success in many lifelong endeavors. The American Association of Physics Teachers (AAPT) (2014) recommend competencies in the undergraduate physics laboratory curriculum are organized into six focus areas. The first focus area, constructing knowledge, captures some of the overarching goals of the undergraduate lab curriculum while the remaining five focus areas, they are modeling, design, technical and practical laboratory skills, data analysis and visualization, and communication.

Laboratory provides activities that allow students to develop content knowledge and skills in science such as manipulating variables and analyzing data (Chali, 2014). In the laboratories the learners learn about facts and laws of Physics and check their truthfulness and learn to make practical use of them. In this method the learness become active. The learners notes down the figures of his observation and on the basis of calculation, draws conclusion so science laboratories are the places and means with the help which all these necessary activities can be performed smoothly and effectively. The laboratory provides a unique opportunity to validate physical theories in a quantitative manner. Laboratory experience demonstrates the limitations in the application of physical theories to real physical situations. The laboratory experiment teaches the role that experimental uncertainty plays in physical measurements and introduces ways to minimize experimental uncertainty. In laboratory students gain more content knowledge and knowledge of process skills compared to traditional instructions. The laboratory approach enhances knowledge and process learning for students (Mishra & Yadav, 2013). When students build their own conceptual understanding of the principles of Physics, their familiarity with the concrete evidence for their ideas leads to deeper understanding and gives them a sense of ownership of the knowledge they have constructed.

Laboratory manual is one of the most important factor in conducting experiment in laboratory. It has descriptions of the laboratories which you will be doing. Laboratory manual contains the laboratory instructions and the relevant section of the text should be read before coming to the laboratory. Laboratory manual guides students preparation for and participation in the experiments. The procedure in each of these exercises has been planned in so that it is possible for the prepared student to perform the experiment in the scheduled laboratory period. College Board (2015) describes the laboratory manual contains of central challenge, background, real world application, inquiry overview, connection to curriculum framework, skills and practices, equipments and materials, timing and length of investigation, safety, preparation, and prelab, investigation, extention, common students challenge, analyzing results, asesessing students understanding, and assessing the science practices.

The observation at Physics laboratory in State University of Medan Indonesia, analysis of *Physics Laboratory Manual*, interviews with Physics college and laboratory assistant the data obtained labs provide detailed instructions which direct students, one step at a time, through an experiment. The problem with these traditional labs is that they are preparing students to think like lab technicians, not like scientists. Physics Laboratory using *cookbook* where is the students are provided with the problem, apparatus and procedure. They are only required to follow the steps and find an answer. Based on two dimensions of inquiry *Cookbook* is the lowest of *level of guidance* and the *engagement in scientic practices* (Zwickl et all, 2013). Therefore, *Cookbook* is not suitable with college because development of critical thinking skills occurs at the higher levels of inquiry. In addition, based on analyzing of syllbus and *cookbook* which used in laboratory showed cookbook is not prepare and serve the lab activities to achieve the competencies that set up in syllabus. In other hand, assessment system is focused into laboratory report.

There are many alternaternative solutions to improve of learning outcomes in laboratory such us Laboratory based instructional intervention (Ojediran et all, 2014), Computer Simulated Experiment (Chukwunenye & Adegoke, 2013), Virtual lab experiment (Bajpai, 2013), Blended Learning (Trapani & Gregory, 2012), Enhancing learning in Laboratory (Yeung et all, 2011), etc. Besides these alternative solutions, inquiry based laboratory is better solution to improve of learning outcomes in laboratory especially for scientific investigation, because students learn by direct experience with the methods and process of inquiry.

"What I hear, I forget. What I see, I remember. What I do, I understand." Xunzi (340 – 245 BC).This Confucian scholar makes a strong point that when it comes to learning. Hearing is not as good as seeing, seeing is not as good as experience, and true learning is only evident when experience produces an action. Notable educational psychologists such as John Dewey (1859-1952), Carl Rogers (1902-1987), and David Kolb (1939) have provided the groundwork of learning theories that focus on “learning through experience or “learning by doing.” Dewey popularized the concept of Experiential Education which focuses on problem solving and critical thinking rather than memorization and rote learning. Rogers considered experiential learning “significant” as compared to what he called “meaningless” cognitive learning. Kolb also noted that concrete learning experiences are critical to meaningful learning and is well known for his Learning Style Inventory (LSI) which is widely used in many disciplines today to help identify preferred ways of learning. A key element of experiential learning, therefore, is the student, and that learning takes place (the knowledge gained) as a result of being personally involved in this pedagogical approach.

Students learn science by direct experience with the methods and process of inquiry. Moreover, they learn better when they measure, touch, feel, make charts, manipulate, draw, record data (Ates & Eryılmaz, 2011). *The National Science Education Standards* (1996) calls scientific inquiry are exhibit curiosity, define questions from current knowledge, propose preliminary explanations or hypotheses, plan and conduct simple investigation, gather evidence from observation, explain based on evidence, consider other explanations, communicate explanation, test explanation. Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. The product of scientific inquiry is the body of scientific knowledge. Scientific knowledge takes four forms: hypotheses, facts, laws, and theories (Staver, 2007).

Inquiry is central to science learning. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (*National Science Education Standards*, 1996). Students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills through individual and social processes. Scientific knowledge is identified as two broad domains, they are content knowledge and process skills. Content knowledge known as declarative knowledge includes the facts, principles, conceptual models, theories and laws which Students are expected to understand and remember. In the other hand, process skills known as procedural knowledge are the techniques used in science, for example, observation, measurement, and developing hypotheses, which Students are to master. Both domains are considered necessary in order for Students to fully understand science concepts and be able to apply them (Hirca, 2013).

Inquiry based laboratory support Physics laboratory work. The role of inquiry based laboratory is to provide students with the opportunity to design and carry out organized investigations of the physical world, to analyze their observations in an attempt to find coherent patterns that can serve as a basis for developing conceptual and mathematical models of phenomena, and ultimately to organize and consolidate their understanding of these models within the theories of Physics. Inquiry based laboratory also provide students with opportunities to experience and observe phenomena by engaging in science practices (College Board, 2015).

Inquiry based laboratories provide a different experience. Inquiry based laboratory places more emphasis on the students as scientists. It places the responsibility on the student to use representations and models to communicate scientific phenomena and solve scientific problems, use mathematics appropriately, engage in scientific questioning to extend thinking or to guide investigations, plan and implement data-collection strategies in relation to a particular scientific question, perform data analysis and evaluation of evidence, work with scientific explanations and theories, connect and relate knowledge across various scales, concepts, and representations in and across the domains (College Board, 2015). Students are expected to communicate their results and support their conclusions with the data they collected. In inquiry based laboratory the concepts behind the experiments are deduced during the lab, the results are unknown beforehand, although predictable, because the students designed the experiments.

There are many benefits to inquiry-based laboratories. Montalbano (2014) found students were engaged in the Inquiry based introductory activity and seemed to realize with care the measurements. Sukarno & Supriyatman (2014) found inquiry learning instructions improving of scince process skills. Parappilly et all (2013) found that student marks either improved (for laboratory reports) or remained the same (for related examination questions), and conclude that inquiry based laboratories at worst do not negatively impact on student performance and may actually benefit student learning. Waters (2012) called conducting inquiry in laboratory, students take “ownership” of the laboratory exercise. Ketpichainarong et all (2010) found Inquiry based laboratory promoted acquisition of content knowledge and skills such as asking good questions, predicting, problem solving, drawing conclusion, and communication.

Eventhough inquiry can not applied in all topic in Physics, learning of wave and optics topics should conducted with inquiry based laboratory (Loyd 2008, Karalina & Etkina, 2013, College Board, 2015). By using inquiry based laboratory students can understand the origins of this cone by constructing multiple explanations, then proposing and designing experiments to test their explanations. This process is the foundation of the investigative science learning environment framework, designed to engage students in the reasoning activities similar to those that physicists use to construct and apply new knowledge. To support the effectiveness of teaching and learning in laboratory, besides preparing a good learning environment in laboratory and infrastructures, laboratory manual also should serves and guide students to investigate Physics. Therefore, Physics Laboratory Manual in Physics Laboratory should be develop based on inquiry lab to improve their investigative skills. Investigations are the “heart and soul” of an inquiry oriented science course, especially one that uses the laboratory as a focus for science activities. Scientific investigations consist of statement of hypothesis, procedure for investigation, plan to record and organize, quality of observations/data, graph, calculation, and forms a conclusion from the experiment." (Doran et al, 2002). Competencies on scientific investigation is the ability to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically. The *National Science Education Standards* (NRC 1996) stress the need for frequent such as weekly inquiry oriented laboratory activities in order to provide students with direct exposure to experiences that reinforce the investigative nature of science.

1.2 Problems Identifications

Based on the problem background of the issues outlined above, some problems can be identified are matters relating to Physics Laboratory. The problems identified as follows:

a. Physics laboratory manual currently using *cookbook*.
b. Students are provided with the problems, apparatus and procedures completely.
c. Laboratory manual provide detailed instructions which direct students, one step at a time, through an experiment.
d. *Cookbook* is the lowest of *level of guidance* and the *engagement in scientic investigations.*
e. *Cookbook* does not prepare and serve competencies to be achieved which set up in syllabus.

f. Assessment system is focused into laboratory report.

1.3 Problems Limitations

Based on the background and problem identification of the issues outlined above, considering the factors involved in the Physics Laboratory is very complex, constrain of the time, funds, ability of the researcher, as well as to research more focused, this study is focused to:

a. Developing of Laboratory Manual based on inquiry based laboratory.
b. Student's performance in conducting experiment in laboratory.
c. Wave and optics course specially for geometric optic topic.

1.4 Questions of Research

The problems in this study can be formulated as are the laboratory manual based on inquiry based laboratory would improve student's competencies on scientific investigation in laboratory?

1.5 Purposes of Research

Based on the question of reserach, the purposes of research are to:

1. Develop the laboratory manual based on inquiry based laboratory.
2. Analyze of student's competencies on scientific investigations in laboratory by using laboratory manual based on inquiry based laboratory.

1.6 Research Implications

The implications of this research is divided in two parts, namely:

1. Practical implications, to provides input and information in Physics experiment using laboratory manual based on inquiry based laboratory.
2. Academic implications, material information in conducting further research.

1.7 Hyphothesis

Hypothesis in this study is developed laboratory manual based on inquiry laboratory increasing the student's comptencies on scientific investigation in laboratory.

1.8 Operational Definition

Inquiry based laboratory is scientific investigation in laboratory which places the responsibility on the student to use representations and models to communicate scientific phenomena and solve scientific problems, use mathematics appropriately, engage in scientific questioning to extend thinking or to guide investigations, plan and implement data-collection strategies in relation to a particular scientific question, perform data analysis and evaluation of evidence, work with scientific explanations and theories, connect and relate knowledge across various scales, concepts, and representations in and across the domains (College Board, 2015).

"Laboratory manual is pilot of students preparation and participation in the experiments which is contains of central challenge, background, real world application, inquiry overview, connection to curriculum framework, skills and practices, equipments and materials, timing and length of investigation, safety, preparation, and prelab, investigation, extention, common Students challenge, analyzing results, asesessing Students understanding, and assessing the science practices." (College Board, 2015).

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