CHAPTER I
INTRODUCTION

A. Background

The scenario of the world in the 21st century saw rapid progress in science and technology. In today's information age, the main goal of the educational system should be to provide students with information acquisition skills instead of directly providing them with the information they need, to prepare individuals for real life and enable individuals to use knowledge and skills they need to be an informed citizen.

In the 1990's the National Science Foundation united science, technology, engineering, and mathematics and created the STEM acronym, a strategic decision made by scientists, technologists, engineers, and mathematicians to combine forces and create a stronger political voice. Literature review and numerous reports reveal that many parties such as policymakers, industry leaders and educators are showing a growing interest in STEM that believed necessary to sustain innovation enterprise, global competitiveness, and national security (Caprile et al., 2015; Honey et al., 2014; Marginson et al., 2013). There is growing concern that the students of today are not prepared for the workforce of tomorrow unless education put more focus and resources towards STEM education at an early age. In educational practices, one of the most significant challenges centers on introducing STEM-related issues and developing the competencies to address the issues students will confront as citizens, because addressing this challenge requires an educational approach that first places life situations and global issues in a central position and uses the four disciplines of STEM to understand and address the problem (Bybee, 2013).

In recent years, STEM education has received growing attention nationwide as STEM plays an increasingly critical role in the nation's economy, competitiveness and security (Fang, 2013). According to numerous articles, STEM education has been defined variously ranging from disciplinary through to transdisciplinary approaches (Burke et al., 2014; Honey et al.,2014; Moore and Smith, 2014). In summary, STEM education is applied approach that is coupled with real world activities involving any of the four disciplines that should not be taught in isolation, just as they do not exist in isolation in the real world. The purpose of STEM education is for all students to learn and to apply basic content and practices of the STEM disciplines to situations they encounter in life (Bybee, 2013).

Indonesia as a big country with a large number of natural and human resources should take a role within that development. To be successful, Indonesia's efforts to improve schools and raise student achievement must include advancing students' understanding of STEM. Through STEM education, students learn to become problem solvers, innovators, creators, and collaborators and go on to fill the critical pipeline of engineers, scientists, and innovators so essential to the future of Indonesia and the nation. The data from *BPS* – Central Bureau of Statistics Indonesia (2010) shown that Indonesia's labors are still dominated by 88 million unskilled labors. 22.1 million skilled labors and only 6.5 million mastered in their sector. It indicates that there is talent gap between the availability of skilled labors which have still not in exact accord to the needs of qualified labors. Currently, junior secondary schools in Indonesia still apply two kinds of curriculum comprised of the School-Based Curriculum (KTSP) and 2013 Curriculum (Kurtilas) which both of them are responsive to the development of science, technology, and art and was developed by taking into account the relevance of education to the needs of life and the world of work. In terms of suitability between STEM education with Indonesia curriculum, it will be a good step to conduct STEM education in Indonesia education system. It is remarkable to note that the need for a skilled STEM workforce is crucial that all young people, regardless of their future career pathway, have the STEM knowledge and skills they need to be an informed citizen in an increasingly scientific and technological society.

Application and transfer of knowledge and fundamental concepts to other subjects and to everyday life is an important goal of education (Bransford et al., 2000). Integrating Science, Technology, Engineering and Mathematics (STEM) helps students connect relevant skills to the use of the skills in real world applications by providing valuable learning contexts and help students develop relevant knowledge and conceptual understanding (Brophy et al., 2008). Studies in complex domains such as solving science problems (Bromage & Mayer, 1981; Heller & Reif, 1984; Robertson, 1986) have suggested that conceptual understanding is associated with connections between science concepts and everyday life and connections among the different science concepts in a discipline. Someone who is good at solving transfer problems does not randomly connect concepts which might occur when using memorized experiences to solve problems but rather integrates the concepts into a well-structured knowledge base (Robertson, 2016). When students have an understanding of a concept, they can think with it, use it in areas other than that in which they learned it, state it in their own words, find a metaphor or an analogy for it, or build a mental or physical model of it, in other words, the students have made the conceptual understanding of their own (Konicek-Moran & Keeley, 2015).

After all, science is all about finding patterns and using those patterns to explain the behavior of our natural world. A Framework for Science Education (NRC, 2012) and the Next Generation Science Standards (NGSS Lead States, 2013) identify the crosscutting concepts. If students were to be familiar with these crosscutting concepts and be able to organize their learning in these groupings, transfer of knowledge and retrieval of information to build conceptual understanding would become much more efficient (Konicek-Moran & Keeley, 2015). In engaging and structured opportunities for exploration, science, technology, engineering and mathematics (STEM) can present phenomena in such a way that crosscutting concepts are highlighted across domains.

Instructional materials play a vital role in teaching and learning at various levels of education, it provide opportunities for children to broaden and deepen their knowledge by providing a variety of firsthand, developmentally appropriate experiences and by helping children acquire symbolic knowledge through representing their experiences (Brown & McIlroy, 2011). Association of American Publishers School Division stated that instructional materials' means all materials that are designed for use by pupils and their teachers as a learning resource and help pupils to acquire facts, skills, or opinions or to develop cognitive processes (Chingos & Whitehurst, 2012). Instructional materials may be printed or non-printed, and may include textbooks, technology-based materials, other educational materials, and tests. Review of middle school curriculum materials to determine how currently available learning materials align with national learning goals and pedagogical criteria rooted in the literature found that the materials covered many topics at a superficial level, focused on technical vocabulary, failed to consider students' prior knowledge, lacked coherent scientific explanations of real-world phenomena, and provide students with few opportunities to develop explanations of phenomena (Kesidou & Roseman, 2002).

Internationally, there is a growing concern for developing STEM instructional material to prepare students for a scientifically and technologically advanced society (English & King, 2015). With global recognition of the importance of STEM education, concerns have arisen from both research and curriculum perspectives about the lack of a unified focus and the need for greater integration of the four disciplines (Barret, Moran & Woods, 2014). The challenge then is how to achieve a more balanced content representation in STEM education. Indonesia confronts several barriers to providing access to the essential, high-quality educational materials necessary for effective STEM education. One is the need to revise existing materials to ensure that they align with and support the current curriculum. The challenges to deepen and apply knowledge across content areas provided by Indonesia curriculum demand tools that will help facilitate this learning.

According to English and King (2015) there are at least two things that might be considered in crafting successful STEM instructional materials. The first is engineering as the driving force behind STEM problem-solving and the second thing is instructional materials should address ways of successfully engaging students in teamwork to solve STEM challenges. The “E” in STEM stands for engineering is what makes STEM different from regular science, technology and math instruction. Good STEM curriculum puts a heavy focus on an engineering design process. The engineering design process (EDP) should be at the heart of the problem-solving approach in instructional material. Despite educational bodies lobbying for an increased focus on STEM, there is limited research on how engineering might be incorporated especially in the secondary school curriculum. A framework of engineering design *PDBU (Pikir, Desain, Buat, Uji)* adapted from the literature on basic technology education in Indonesia (Chandra & Rustaman, 2009) served as a basis for the study.

Previous research suggests that engineering design is an effective approach to support science learning (Schnittka & Bell, 2011). As an example, a well-documented and effective approaches for which design provides a vehicle for learning is learning by design, which is a model of constructing and testing real devices that provides students with opportunities to test their conceptions and discover the holes in their own knowledge as well as predict the performance of their designs (Kolodner, 2002). Parallel to accounts of design approaches to enhance science learning are those that use science as a vehicle for prompting design. For example, Lewis (2006) describes two activities that ask students to develop design ideas by applying science concepts they learned previously. The first activity involves application of electrical and mechanical energy concepts to the design of wind turbines, the second activity applies thermal expansion principles into the design of bimetallic household products.

The second thing is instructional materials should address ways of successfully engaging students in teamwork to solve STEM challenges. According to Bybee (2013) STEM programs can introduce complex communications and social skills as a part of laboratories and investigations that would include group work that culminates with the use of evidence to formulate a conclusion or recommendation. When there is peer support and encouragement for learning, there is an atmosphere more conducive to conceptual change and understanding (Sinatra & Pintrich, 2003). Many careers in STEM, like careers in other fields, involve working in a team to a certain extent although scientists and engineers may have a lot of solitary tasks, they are often part of larger projects that involve collaboration. In surveys in which employers of STEM graduates are asked to list the skills they have found most lacking in their recent hires, teamwork is one of the skills mentioned most frequently, along with the communication, creative thinking and critical thinking skills (Brent & Felder, 2016). Work structures involving teams are often more efficient and effective than individual work (Hoegl & Gemuenden, 2001).

Teamwork refers to the process by which a number of individuals share their skills, knowledge, resources to work together in a cooperative environment for achieving better result for common goals as well as individual development (Brown & McIlroy, 2011). This brings one of the most needed life skills into the curriculum, and develops synergy needed for problem-solving. According to Summers and Volet (2008), when students work together in a group, they usually split the task into small, separate pieces. Each group member then works on their own small piece and, at the end, the separate pieces are joined together. The main advantage gained is division of labor. The disadvantages are a group member not completing their task on time, the responsibility for assembling the final product falls on one person, members do not necessarily contribute to each other's work, and members do not usually understand what the others have done. Research often report that students typically do not know how to communicate and that they have insufficient experience and preparation for working as part of a team (Burdett, 2003). Yet little has been done to effectively address this issue.

Most instructional processes focus on individual contributions rather than on managed group efforts (Willis et.al., 2002). Although many schools have recognized the need to assign group projects and have begun efforts to improve science instruction in this regard, students seldom receive any specific training on how to function collaboratively before such assignments are given, and little attention is given to how teams are formed. Consequently, teams often fail to function effectively. More importantly, students do not learn much from participating on dysfunctional teams and often develop negative views about the value of teamwork.

Science curriculum for junior secondary school include simple machines concept especially levers in human body as an integrated topic, in which students learn about devices with few or no moving parts that make work easier as well as its relationship with human body movement. A machine is a device that applies science, technology, engineering and mathematics on its work principle. This concept was chosen in terms of its suitability with STEM lesson where students learn science concept of how skeletal muscle produce movements in human body related with lever system, technology concept where students learn about many products of a simple lever which is useful to make work easier, engineering concept where students have chance to create the design of lever system and connecting it with human movement system and mathematics concept where students calculate the mechanical advantage of levers.

According to these problems, the instructional materials must provide guidance for teachers to help students learn and practice successful team behaviors and personal interaction skills and construct engineering design behavior. This research is purposely made to answer the call for the need of promoting students' conceptual understanding, engineering design behavior and teamwork skills through STEM based instructional materials which help students to prepare for real life, enable them to use knowledge and skills they need to be an informed citizen and should involve students and teachers in using this process throughout the STEM challenge, from clearly identifying the problem to creating and developing solutions.

B. Problem Statement

How does the effectiveness of STEM based instructional material and non-STEM based instructional material in fostering students' conceptual understanding and its effect towards students' engineering design behaviors and teamwork skills?

1. Research questions

In the light of the problem above, this study will be guided and structured around the following research questions:

a) How does the difference of students' conceptual understanding between STEM-based instructional material class and non-STEM based instructional material class?
b) How does the difference of students' engineering design behavior between STEM-based instructional material class and non-STEM based instructional material class?
c) How does the difference of students' teamwork skills between STEM-based instructional material class and non-STEM based instructional material class?

C. Scope of study

In the proposed study, science concept that learnt by students only focused on specific concepts that are relevant to the design task, both learning science and learning design goals are essential and in alignment with the national curriculum.

This study is not examined all of simple machines concept, it is limited into lever as the physics of body mechanics for 8^{th} grader of secondary school students. The effect of STEM based instructional material towards students' conceptual understanding being investigated through multiple choice conception tests. To characterize observable patterns of student design behaviors within the utilizing of STEM based instructional material during learning process, the informed design coding protocol based on the *Informed Design Learning and Teaching Matrix* (Crismond and Adams, 2012) were used. Students' teamwork skills were investigated based on observation and rating scale through Comprehensive Assessment of Team Member Effectiveness (CATME) was developed by Loughry, Ohland, and Moore (2007).

D. Aim of the Study

In view of the above, the purpose of this study are to examine the effectiveness of science instructional material that developed based on STEM framework benefits students learning on the degree to which students improve conceptual understanding, generate engineering design behaviors and teamwork skills, to improve learning results in science education by pedagogical means and to suggest approach of teaching that may promote STEM education.

E. Significance of Study

This study is expected to give contributions for researcher, teachers, students and readers as follow:

1. This research is expected to give information about the implementation of STEM based instructional material in secondary school
2. This research is expected to give information about the effectiveness of STEM based instructional material to help secondary school students to generate conceptual understanding, engineering design behaviors and teamwork skills
3. Through the implementation of STEM based instructional material, it is expected that either students or teachers will be able to understand the

integration of Science, Technology, Engineering and Mathematics (STEM) comprehensively.

4. This research can be an alternative method to conduct STEM instructional process in a classroom.
5. As the reference for the other researcher in doing research with same focus of study

F. Assumption

This research study is anchored on the assumption that the implementation of STEM based instructional material in science instruction helps students to improve conceptual understanding, promoting engineering design behaviors and teamwork skills resulted from the availability of engineering as the driving force behind STEM problem-solving and an effective approach to support science learning and the ways of engaging students in teamwork to solve STEM challenges (English & King, 2015).

G. Hypotheses

The hypotheses of this study is limited to students' conceptual understanding improvement, therefore the research hypotheses is formulated based on first research question, which is stated that there will be significance difference of students' conceptual understanding improvement between experiment group that learn science through STEM-based instructional material and control group that learn science through non-STEM based instructional material that shows that STEM based instructional material in science instruction is effective in improving students' conceptual understanding. The null hypothesis defined as there is no significance difference of students' conceptual understanding improvement between control group and experiment group.

H. Organizational Structure

This thesis comprises five chapters that is started with introductory chapter which describes the background and statement of the problem, limitation of the study, assumption of the study, aims of the study and finally, benefits of the study and operational definition. It starts by focusing on the main goal of the educational system in 21st century that shows growing interest in STEM until STEM education has received growing attention nationwide. The research started when Indonesia with the condition of talent gap appear between the availability of skilled labors which have still not in exact accord to the needs of qualified labors must include advancing students' understanding of STEM through implementation of STEM based instructional material to promote students' conceptual understanding, engineering design behaviors and teamwork skills. In order to overcome this obstacle, the objectives of the study were determined, and subsequently some research questions were formulated. The second chapter provides literature review of the study, this chapter started by focusing on theory of STEM education, instructional material, levers in human body as STEM concept, conceptual understanding, engineering design behaviors and teamwork skills. Finally, STEM based instructional material was implemented in this study for the science teaching and learning process specifically on lever in human body concept that was discussed along with an attempt by the researcher to justify the research. The third chapter examines research methodology. The chapter begun by detailing the participant of the study and the time and location under which the various stages of research were carried out. Next, it dealt with the method and design of research, operational definition and data collection instruments. The fourth chapter presented data analysis and interpretation. Descriptive and statistical analysis such as independent sample t-test, frequencies, tables and percentages were used in the data analysis and summaries. The results of both qualitative and quantitative data were presented by using tables and graph. The last chapter presented conclusion that was taken from the research and suggestion for further research.

I. Operational Definition

To avoid misinterpretation of some terms that is used in this research, hence the explanation of some terms is needed in order to make it more effective and operational. The terms are as follow:

1. Conceptual understanding is defined as the ability to think by understanding knowledge and linked to form a concept and develop mental models about the way the world operates in accordance with current scientific theory. Students' conceptual understanding measured through students' answer on conception test that was formulated based on levels of cognitive in Bloom Taxonomy.
2. Engineering design behavior refers to observable students' behaviors when conducting engineering design process consists of define the problem, gather pertinent information, generate multiple solutions, analyze and select a solution, test and implement the solution. Students' engineering design behaviors observed through the appearance of engineering design strategies and associated patterns that contrast beginning versus informed design behaviors through Informed Design Learning and Teaching Matrix instrument.
3. Teamwork skills refer to the process by which a number of individuals share their skills, knowledge, resources to work together in a cooperative environment for achieving better result as well as individual development and enables students to bring their ideas together thus leading to to find solutions to problems. Students' teamwork skills observed by using Comprehensive Assessment of Team Member Effectiveness (CATME) that collects self-ratings, peer ratings and teacher ratings on five dimensions of team-member contributions that were developed based on the teamwork literature and original empirical research.