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Teacher Perceptions of Inquiry and STEM Education in Bangladesh

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by

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ABSTRACT

This dissertation reports lower secondary science teachers perceptions of current practice in Dhaka, Bangladesh concerning inquiry and STEM Education in order to establish a baseline of data for reform of science education in Bangladesh. Bangladesh has been trying to incorporate inquiry-based science curricula since the 1970s. Over time, the science curricula also aligned with different international science education movements such as Science for All, Scientific Literacy, Science, Technology, and Society. Science, Technology, Engineering, and Mathematics (STEM) is the most recent science education movement in international science education. This study explored current practices and perceptions of lower secondary science teachers in order to establish a baseline of current practice so that future reform recommendations may be pursued and recommendations made for Bangladesh to overcome the inquiry-based challenges and to incorporate new STEM-based science education trends happening in the US and throughout the world.

The study explored science teachers perceptions and readiness to transform their science classrooms based on self-reported survey. The survey utilized Likert-type scale with range 1 (very strongly disagree) to 6 (very strongly agree) among four hundred lower secondary science teachers, teacher training college faculty, and university faculty. The data is presented in four different categories: curriculum, instruction, assessment, and professional development.

Results indicated that the participants understand and practice a certain level of inquiry in their science classrooms, though they do not have adequate professional development. Participants also stated that they do not have sufficient instructional materials and the curriculum is not articulated enough to support inquiry. On the other hand, the participants reported that they understand and practice a certain degree of inquiry and STEM-based science education, but they also state that the current curriculum and instructional materials are not sufficient to practice inquiry nor to integrate more than one or two disciplines with science as is required in STEM integrated teaching. Finally, this study recommends a framework for science education reform for Bangladesh based upon a combination of successful international science education reformation practices.

Dedication

To my parents who brought me in this world and to my teachers who passed their knowledge.

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I would like to express my sincere thanks to my advisor Dr. David Crowther and the doctoral committee members Dr. John Cannon, Teruni Lamberg, Cleve Maddux, and Eric Wang at the University of Nevada, Reno. It has been a great pleasure to work with my advisor and the committee members in my doctoral journey. Their constant and rigorous suggestions have given me to accomplish my mission successfully.

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ACRONYMS

AAAS American Association for the Advancement of Science

CCSS Core Curriculum State Standards

MoE Ministry of Education

NCTB National Curriculum and Textbook Board

NGA National Governors Association

NGSS Next Generation Science Standards

NSF National Science Foundation

NRC National Research Council

NSES National Science Education Standards

NSTA National Science Teachers Association

OECD Organization for Economic Cooperation and Development

STEM Science, Technology, Engineering, and Mathematics

STS Science, Technology, and Society

CHAPTER ONE

INTRODUCTION

Bangladesh is a leading developing country in the world. Since its independence in 1971, the nation has been progressing tremendously socially and economically along with the rest of the world. However, its colonial education is the challenge and drawback for becoming a mid-level developed country. Therefore, it is imperative for Bangladesh to consider newer educational trends in order to develop economically and because more global. Now is the time for Bangladesh to update for the British and Colonial education model and to embrace inquiry-based STEM (Science, Technology, and Mathematics) education for preparing the country's citizens for 21st century and the country's economy.

Science, Technology, Engineering, and Mathematics (STEM) Education is the future of social and economical development of 21st century society. As the leading developed country's of the world, the United States has launched K-12 STEM Education on the last few years. President Obama stated that:

> One of the things that I've been focused on as President is how we create an all-hands-on-deck approach to science, technology, engineering, and mathematics. We need to make this a priority to train an army of new teachers in these subject areas, and to make sure that all of us as a country are lifting up these subjects for the respect that they deserve. President Barack Obama (White House, 2013)

Although there is not a unique definition of STEM education, several groups have tried to capture the generalized idea. The New York STEM Education Collaborative in conjunction with the National STEM Collaborative came up with one of the first broadly circulated definitions which stated:

> STEM Education refers to utilizing the Content Standards in the teaching and learning of the Science, Technology Education, Engineering and Mathematics(STEM) disciplines, in an innovative, integrated, collaborative, and applied fashion to a level of challenge sufficient for college and/or career readiness (New York State STEM Education Collaborative, 2009, pp.0).

Another widely circulated definition comes from Tsupros, Kohler, and Hallinen (2009) in which they stated:

> STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (pp.1)

The National Science Teachers Association (NSTA) states that Science, Technology, Engineering, and Mathematics (STEM) should not be another discipline or subject area, but rather an instructional strategy to help develop the innovators of the future (Gerlach, 2012).

Inquiry in STEM Education

What is Inquiry?

Scientific inquiry has been described by different groups in in various ways. For example, the *National Science Education Standards* defined scientific inquiry as:

> 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. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (NRC, 1996, p.23)

Teaching science through inquiry allows students to conceptualize questions, seek possible explanations to respond their questions (NRC, 2000). However, our traditional science teaching in Bangladesh prevailed through a dearth of science facts with technical scientific words. Ultimately, this traditional science education prepares for taking tests, which is not the accepted way how scientist practices science. In opposition to traditional methodology, the *NSES* recommended that science teachers should sustain students' curiosity which would help them to develop the sets of scientific inquiry abilities (NRC, 2000).

Project 2061 defined inquiry slightly different in *Benchmark for Science Literacy*:

> Scientific inquiry is more complex than popular conceptions would have it. It is, for instance, a more subtle and demanding process than the naive idea of "making a great many careful observations and then organizing them". It is far more flexible than the

> rigid sequence of steps commonly depicted in textbooks as "the scientific method." More imagination and inventiveness are involved in scientific inquiry than many people realize. Individual investigators working alone sometimes make great discoveries, but the steady advancement of science depends on the enterprise as a whole. (AAAS, 1993, p.9)

The National Science Teachers Association defined scientific inquiry another way than AAAS and NRC:

> Scientific inquiry is a powerful of understanding science content. Students learn how to ask questions and use evidence to answer them. In the process of learning the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions. (NSTA, 2004, para. 3)

Science as inquiry has been at the forefront of science education reform since mid-1990s. (Julie Luft, 2008). Dewey (1910) advocated for the inclusion of inquiry in K-12 science curriculum. Dewey emphasized "scientific thinking and attitude of the mind for the students rather than just on scientific facts". He recommended inquiry in science education as a science teaching strategy rather than the rigid six step scientific method. He encouraged students to address a scientific problem by applying observable phenomena that enrich their personal experience of knowledge (p.122).

Following Dewey, Rutherford (1964) showed special interest in teaching science using the inquiry method. He advocated the importance of the inquiry method to science teachers, science educators, and scientists. He warned about rote memorization where students can learn the mere facts and minutiae of science (p.80). He claimed that there was an organic connection between process and content in science.

Rutherford (1964) clarified teaching science as inquiry in two general ways- "inquiry as content" and "inquiry as technique" (p.80). He added that inquiry as content refers to a certain science inquiry characteristics within a science field. He argued that certain patterns of inquiry are the parts of the scientific disciplines though they act as certain process. On the other hand, he considered "teaching science as inquiry" as a definite technique or strategy for learning a particular scientific content, known as inquiry method.

According to Schwab (1960) there are two types of inquiry in science education: stable and fluid (p.181). Schwab and Brandwein (1962) believed science to be a series of new information or evidence. He added that when students continually experience a series of scientific information, then they will revise their existing conceptual structure of science. Schwab defined stable inquiry as a growing body of knowledge and fluid inquiry as a invention of new conceptual structures that reveal science.

Herron (1971) wrote a foundational paper on the role of scientific inquiry in science education and the value of scientific inquiry for students. Schwab and Brandwein (1962) pointed out that inquiries are guided by substantive structures which are partially tied to the phenomena within a discipline. Herron remarked that the level of detail appropriate for curricular materials should be specific and flexible enough to take account of variation in modes of inquiry that occur among different scientific disciplines (i.e. physics, biology, etc.). He added that the logical framework for scientific inquiry have to be structured to enable us to distinguish a variety of curricular materials.

The American Association for the Advancement of Science (AAAS) initiated Project 2061 in 1985 and has since advocated for improving scientific literacy across the America (NRC, 2003). Scientific literacy encompasses a wide range of content, including inquiry, history and nature of science, personal and social perspectives of science, science, and technology, in addition to the science domains of life science, physical science, and earth and space science.

The National Research Council (NRC) and the Council on Educational Standards and Testing developed the National Science Education Standards (NSES) in 1996. The National Science Education Standards (NSES) the first science standards in the U.S. and was the focus of the science education reform in the United States for over 15 years.

The goal of NSES was to create opportunity for every K-12 student for what they should be expected to know and be able to get experience in science education. They specially introduced the inquiry method for teaching science in K-12 education in the U.S. The inquiry method in the *National Science Education Standards* demonstrated how inquiry is responsible for science education, can provide young people with the opportunities they need to develop their scientific understanding and ability to inquire (NRC, 2000).

The *Next Generation Science Standards (NGSS)* were published in 2013 and as the latest set of science education standards for K-12 science education in the U.S. The NGSS have developed based upon the *framework for K-12 Science Education.* This framework was developed based on the previous research of the *Science for All Americans* and *Benchmarks for Science Literacy* (1993), developed by the American Association for the Advancement of Science (AAAS), and the *National Science Education Standards* (1996), developed by the NRC (NRC, 2012).

A framework for K-12 Science Education has recommended three-dimensional science learning. It integrated the context for the content of science there to the Practices of Science and Engineering (PSE), the way science knowledge is acquired and understood in the Disciplinary Core Ideas (DCI), and the way individual sciences are connected through concepts across discipline with universal meaning in the Crosscutting Concepts (CCC).

Essential features of Science Classroom

Inquiry in science classroom has five essential features as described in *Inquiry and the National Science Education Standards* (NRC, 2000). The essential features are : (a) learners engage in scientifically oriented questions, (b) learners give priority to evidence in responding question, (c) learners formulate explanations from evidence, (d) learners connect explanations to scientific knowledge, (e) learners communicate and justify explanations (p.29).

Lederman (2004) pointed out three different components of inquiry: as a teaching strategy, a set of student skills (develop individual skills and forming logical conclusions), knowledge (Develop understanding) about inquiry.

Banchi and Bell (2008) presented the inquiry continuum with low-level structured to high level open inquiry. The continuum created based on how much information is provided to students and how much guidance will provide as the teacher (Banchi and Bell, 2008; Herron, 1971; Schwab 1962). In other words, the continuum always for a progression of more structured to less structured Forms of Inquiry. They incorporated four level continuum: conformation, structured, guided, open (p.26).

Inquiry Based Instruction

Inquiry-based science instruction uses the instructional part of the science inquiry method. Minner, Levy and Century (2010) have done research about the impact of inquiry-based instruction in science education from 1984 to 2002. They analyzed 138 studies about inquiry based instruction and found that there is a clear indication of positive achievement of science education by using inquiry based instruction in science. Their analysis showed that inquiry-based instruction stressed on students' active thinking and drawing conclusion based on their investigated data. Additionally, actively engaged students increased conceptual understanding through the scientific learning process are passive learning processes.

There is no concrete information about the first inauguration of inquiry-based instruction. However, the nature of learning and teaching give the emergence of the type of instruction in a certain discipline. Cakir (2008) pointed out that constructivist-based teaching-learning materials induced inquiry-based and hands-on based activities for exploring science concept.

Science Education in Bangladesh

Bangladesh is a new state in an ancient land. The history of science education in Bangladesh is in the inception stage similar to when it became a state in 1971. As a part of the ancient Indian civilization, it has a traditional education. However, it also has a western education and westernized science education due to the British colonization of the Indian sub-continent in the 19th century (Rahman, Hamzah, Meerah, and Rahman, (2010; Bhowmik, 2005). The Indian sub-continent as well as Bangladesh inherited the British science education system. However, it is highly centralized, urban based, for elite class, and alienated from the masses (Rahman et al., 2010, Bhowmik, 2005). The colonized government used science education as a “Filtration Theory” for the colonized citizens (Bray, 1993). The lower socio-economic people cannot afford such education expenditures. Besides this, socio-religious factors are another issue in failing to westernize science education since the 19th century in Bangladesh.

Bhowmik (2005) has stated that in the 1960s, science education tried to align the education system with the rest of the world’s education advancement. He also said that there were a few concepts and terms added in the science curricula; inquiry, discovery, and scientific processes for enhancing science teaching, and developing science concepts.

After 1971, as a sovereign nation, the present science education system emerged. The National Curriculum Committee named as the Dr. Qudret-e-Khuda education commission started to work on brand new science curricula as well as other disciplinary areas for the new independent nation. The committee recommended that the new science curriculum should start to introduce science in the first grade. However, there should not be any textbooks in the first and second grade. There would be an environmental science book from grade three to five for introducing science. Additionally, the commission also recommended a general science book from grade six to eight as part of teaching science in the lower secondary level. The Secondary and higher secondary level science education was highly specialized by discipline such as physics, chemistry and biology.

Secondary and higher secondary science education are highly designed for supporting the job market and industries rather achieving scientific literacy since 1974. These introduces were for all areas of education and over time, eventually failed. Another science education reformation initiative took place in 2006, named the “uni-track” science curriculum. This curriculum proposed that uni-track science curriculum should extend from to eighth to tenth grade. This curriculum should helped the students get better chances for equal learning in science. However, the curriculum was rejected by various stakeholders and was not able to be implemented (Siddique, 2008). It’s not the first curriculum to fail in the country. There were “hands-on practices” based science that was introduced in the 1982. The country implemented “learning by doing” textbooks for the secondary level (Tapan, 2010). Tapan also added that this curriculum also failed to evaluate students based on new curriculum teaching and lab resources. The institutional failure also included the lack of resources and the physical infrastructure to implement this kind of science curriculum.

Problem Statement

Students' views of transmissive style teaching (Mojumdar, 2015) agreed with Tapan (2010) who reported the frustrating scenario of the traditional one-way science teaching practice in Bangladesh. Tapan found science teachers teach the same content in the same way they had been students. There are teachers' guides in Bangladesh that introduce many innovative teaching methods and are designed to help teachers improve their teaching of science. However, Tapan suggested that science teachers are reluctant to use such innovative methods due to the lack of interest, motivation, and proper in-service training and the preference to continue to teach students via rote learning (Tapan, 2010).

Due to the lack of training, in test and monitoring, the inquiry-based science curriculum failed implementation in 90's (Tapan, 2010). Tapan also added that the lack of instructional resources in the classrooms was another reason that the inquiry-based curriculum failed. The schools were unable to provide appropriate resources and science teaching aids for incorporating inquiry in the science classrooms (NCTB, 1996). Additionally, the science teachers were not well enough equipped with inquiry-based activity and the assessment system was not synchronized to the new curriculum. Additionally, parents were not informed and did not cooperate enough to move such a shift in the educational system. Tapan's (2010) assessment on shifting the inquiry-based curriculum to the content-based curriculum (NCTB, 1996) was remarkable. He criticized that the revisions of science curriculum were done because of the mentioned implementation weakness of the previous curriculum but with this change they could not achieve the goal and in my opinion, science education in Bangladesh was not improved but deteriorated. He also added that the faults were not with the textbooks but with implementation process because of NCTB could not prepare teachers through proper training. Additionally, another reason of reluctancy was the lack of teaching resources, appropriate training on inquiry, proper support to implement inquiry.

Mojumdar (2015) found textbook based instruction as another highly challenging for issues incorporating innovative science teaching as inquiry-based instruction, in his current study. He found that textbook based learning science concepts have little application of scientific knowledge to everyday life. School science, as a result, must seem to them to have no relation to their life. Rather, it is about memorizing facts, laws, information and postulates, and practicing and sitting in exams to achieve good grades. The students pointed out that "studying science in schools means memorizing information and a number of facts and laws for responding to the exam questions. Since we are not taught science practically, we do not understand many of scientific events". Therefore, this study explored the current teaching practices in order to established and formed foundation for which Bangladesh can make an important play for science education.

Purpose Statement

The purpose of this survey study was to explore the current science education practices for middle level science teachers defined in Bangladesh as lower secondary level teachers working in grades 6-8 in Dhaka, Bangladesh. The focus of this research was the science teachers' current self-reported practices and attitudes towards teaching science within a traditional, British developed, educational system. Although the main focus of this research was science education practices in classrooms as reported by teachers. The purpose of collecting this baseline information is to give the teacher perspective of current science education practices so that a place for improving science education in Bangladesh may be challenged and implemented and then copied back to the base form data to see if important was made.

Research Questions

The following questions was examined:

1. What are the science teachers' current practices and attitudes (beliefs?) towards teaching science 6-8th grade schools in Dhaka, Bangladesh?

(A) What current teaching methods do science teachers report using in their classrooms?

(B) What is the current level of integration of engineering and technology is reported by science teachers?

(C) What is the current level of integration of teaching mathematics within science reported by science teachers?

(D) What is the current level of inquiry based science instruction reported by the science teachers?

(E) How open are do teachers trying to new forms of science instruction?

Rationale and Context:

In Bangladesh, secondary education comprises of three levels: junior secondary (Grades VI-VIII: ages 11 to 14), secondary (Grades IX and X: ages 14 to 16), and higher secondary (Grades XI and XII: ages 16 to 18). All students study a compulsory general science subject until Grade VIII. Students choose one of three streams- science, humanities, and business studies from Grade IX. Each stream studies its own elective subjects. Humanities and business stream students also study one general science subject. Junior secondary level was only considered for this study.

STEM based science education is the contemporary shift in science education. Science education has introduced inquiry based science education since the early 1960's. In 1974, Bangladesh formally introduced inquiry in national science curriculum and introduced inquiry-based textbook in 1987. Both the curriculum and the inquiry-based textbook failed to implement successfully. Tapan (2010) found that the inquiry-based curriculum and textbook failed to be implemented because of lack of proper teacher training and appropriate parents' cooperation. The inquiry-based assessment was not well designed to assess students' achievement. On the other hand, teachers were not well trained to teach and assess inquiry-based science and assessment. As a consequence, the country has moved to highly content-based science education since 1994. Bangladesh realizes that inquiry and STEM based science education an important features for future. Therefore, before introducing STEM education as new paradigm shift in science education it is necessary to find the issues and teachers expectations as a baseline data set, to make this initiative successful.

Limitations of the Study:

The main research limitation is the location and school selection. Due to time and socio-political reasons, the study will be limited into Dhaka City, Bangladesh and collected data from the best convenient schools.

One of the biggest challenge for the researcher was to translate the tools into Bengali since english is their second language. Even this is one of the challenges for the researcher to collect the whole data in another language and summarize the findings in second language. Therefore, one of the major shortcomings for this research is to collect the data in another language and translate them in second language.

Related Terms Definition

Scientific Inquiry

Science defines as both the body of knowledge and the process. Scientific knowledge is a function of the process by which scientists come to obtain that knowledge. Bybee (2002) mentioned scientific inquiry as a process of empirical evidence for explaining the natural world by the scientist.

STEM Education

STEM is the acronym of science, technology, engineering and mathematics. STEM is divided into two categories: STEM education and STEM workforce for industry. STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros, 2009).

CHAPTER TWO

Literature Review

The literature reviewed for this study included the review of theoretical, research, and practitioner based articles in science education. This review also draws upon research from both qualitative and quantitate research paradigms. More specifically, this literature review centers on research as it relates to historical background of inquiry, inquiry in STEM education and achieving 21st century skills through practicing inquiry. The overall goal of such an extensive approach was to provide a theoretical and conceptual framework for this study.

Inquiry in STEM Education

What is Inquiry?

Scientific inquiry has been defined in various ways by different groups. For instance, the *National Science Education Standards* defined scientific inquiry in as:

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Teaching science through inquiry allows students to conceptualize questions and to seek possible explanations to respond their questions (NRC, 2000). However, traditional science teaching in Bangladesh prevailed through a dearth of science facts with technical scientific words. Ultimately this traditional science education prepares for taking tests which is not the accepted way how the scientist practices science. In opposition to current methodology, the *NSES* recommended that science teachers should sustain students' curiosity which would help them to develop the sets of scientific inquiry abilities (NRC, 2000).

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The National Science Teachers Association defined scientific inquiry another way than AAAS and NRC:

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Historical Perspective

Dewey

> Scientific method is not just a method which it has been found profitable to pursue in this or that abstruse subject for purely technical reasons. It represents the only method of thinking that has proved fruitful in any subject that is what we mean when we call it scientific. It is not a particular development of thinking for highly specialized ends; it is thinking so far as thought has become conscious of its proper ends and of the equipment indispensable for success in their pursuit. (Dewey, 1920, p.127).

Dewey (1910) advocated for the inclusion of inquiry in K-12 science curriculum. Dewey emphasized “scientific thinking and attitude of the mind for the students rather than just on scientific facts”(p.127). He recommended inquiry as a science teaching strategy rather than the rigid six step scientific method. This thought from the early 1900’s reflected in current science education teaching. The *Framework for K-12 Science Education* states that asking questions is essential to develop scientific habits of mind. It also recommended that the ability to ask well defined questions is important to become scientifically literate (NRC, 2012). Dewey encouraged students to address scientific problems by applying observable phenomena that enrich their personal experience of knowledge (Dewey, 1916).

As a prelude to what declared into the scientific method, Dewey mentioned logical phases based on the conception of complete act of thought. Dewey identified logical steps to complete scientific task and theory: (1) a felt difficulty, (2) its location and definition, (3) suggestions of possible solutions; development by reasoning of bearing of the suggestions, and (5) further observation and experiment, leading to its acceptance or rejection- conclusion of belief or disbelief (Dewey, 2005). Bybee (2010) described that these five steps of the scientific endeavor have influenced science teachers' conception of scientific inquiry.

The fact that Dewey's five phases became a rigid sequence introduced in science textbooks and classrooms in unfortunate. John Dewey did not perceive the methods of science as a rigid process. Dewey (1910) argued for the importance of using the scientific method in school science programs and presented a dynamic view of inquiry. He also mentioned that:

> I mean that science been taught too much as an accumulation of ready-made material with which students are to be able to made familiar, not enough as a

> method as a habit of mind. After a pattern of which mental habits are to be transformed. (Dewey 1910, p.121)

Dewey further elaborated on scientific method as a habit of mind which include the abilities of inquiry, the nature of science, and understanding of subject matter. He described knowledge as:

> Such knowledge never can be learned by itself; it is not information, but a mode of intelligent practice, a habitual disposition of mind. Only by taking a hand in the making of knowledge, by transferring guess and option into belief authorized by inquiry, does one never get a knowledge of the method of knowing. Because participation in the making of knowledge has been scant, because reliance on the efficacy of acquaintance with certain kinds of facts has been current, science has not accomplished in education what was predicted for it. (Dewey 1910, p.125)

Dewey also emphasized that science teaching had suffered due to ready-made knowledge, so much subject-matter of fact and law, rather than the effective method of inquiry in any subject matter. Dewey envisioned something different for the teaching of science in schools. He described that:

> I do not mean that our schools should be expected to send forth their students equipped as judges of truth and falsity in specialized scientific matters. But that the great majority of those who leave school should have some idea of the kind of evidence required to sub- stantiate given types of belief does not seem

> unreasonable. Nor is it absurd to expect that they should go forth with a lively interest in the ways in which knowledge is improved and a marked distaste for all conclusions reached in disharmony with the methods of scientific inquiry. (Dewey, 1910, p.126)

Dewey's remarks for what children should learn as part of science instruction in school leads to the scientific scientific habit; we need to discover how to mature and make effective these scientific habits as the problem of problems in our education (Dewey, 1910).

Rutherford

Following Dewey, Rutherford (1964) showed special interest in teaching science using the inquiry method. He advocated the importance of the inquiry method to science teachers, science educators, and scientists. He warned about rote memorization where students can learn the mere facts and minutiae of science. He claimed that there was an organic connection between process and content in science.

Rutherford (1964) clarified the organic connection of teaching science as inquiry in two general ways; "inquiry as content" and "inquiry as technique". He added that inquiry as content refers to certain science inquiry characteristics within a science field. He argued that the certain patterns of inquiry are the parts of the scientific disciplines though they act as a certain process. On the other hand, he considered "teaching science as inquiry" as a technique or strategy for learning scientific content, known as the inquiry method or approach to teaching science.

Rutherford connected teaching science as inquiry and the knowledge base for doing so. He concluded that until science teachers acquire "a rather grounding in history and philosophy of the sciences they teach, this kind of understanding will elude them, in which event not much progress toward the teaching of science as inquiry can be expected" (Rutherford, 1964)

Herron (1971) spoke about in what detail scientific inquiry may be examined for the purposes of science education. Schwab (1966) pointed out that inquiries are guided by substantive structures, which are partially tied to the phenomena within a discipline. Herron said that the level of detail appropriate for curricular materials should be specific and flexible enough to take account of variation in modes of inquiry that occur among different scientific disciplines (i.e. physics, biology, etc.). He added that the logical framework for scientific inquiry have to be structured to enable us to distinguish a variety of curricular materials (p.171).

The identification of science with a certain limited field of subject matter, ignoring the fact that science is primarily the method of intelligence at the work in observation, in inquiry and experimental testing. Fundamentally, what science means and stands for is simply the best ways yet found out by which human intelligence can do the work it should do, ways that continually improve by the very processes of use.(Dewey, 1916)

The end of science teaching does not make us aware what constitutes the more effective use of mind, of intelligence. It gives us a working sense of the real nature of knowledge, of sound knowledge as distinct from mere guess work, opinion, dogmatic belief of whatever. Science is not only knowledge, but it is knowledge at its best, knowledge in its tested and surest form.

Schwab

Schwab is one of the pioneers of introducing inquiry in science education. Schwab brings his views on inquiry to education by stating that:

> we are asked to discover, select, motivate, and launch an increasingly large group of fluid inquiries and original engineers and a non-science public which understands the nature and consequences of the work these scientists do. (Schwab, 1960, p.1)

Schwab (1958) grounded his argument to teach science through inquiry. He raged that the present methods of teaching sciences lies in the fact that science itself has changed. A new view concerning the nature of scientific inquiry now controls research.

When Schwab discussed the implication of these changes for education, he pointed out that science textbooks and science teachers were presenting science a way that was inconsistent with modern science. According to Schwab (1966), science was taught "as a nearly unmitigated *rhetoric of conclusions* in which the current and temporary constructions of scientific knowledge are conveyed as empirical (p.24).

The implications of Schwab's ideas were, for their time, profound. He suggested first that science should be presented as inquiry, and second that students should undertake inquiries as the means to learn science. To achieve these changes, Schwab (1960) recommended that science teachers first look to the laboratory and use these experiences to lead rather than lag the class- room phase of science teaching.

Schwab also proposed an approach, which he referred to as *inquiry into inquiry*. In this approach, teachers provide students with readings, reports, or books about research. They engage in discussions about the problems, data, role of technology, interpretation of data, and conclusions reached by scientists. Where possible, students should read about alternative explanations, experiments, debates about assumptions, use of evidence, and other issues of scientific inquiry.

Scientist innovate new ideas and facts through different kind of methods. There is continual debate among the scientist about the scientific process or inquiry for any specific test. Different scientists execute different kinds of experimental design based on their scientific areas, literature, hypotheses and compatible methods. Schwab (1960) pointed out the variation of mode of inquiry, stating "a mode of inquiry discredited by one scientist, dismissed at one time, discarded in one science, reappears and is fruitful in other hands, at other times, or in other sciences (p.1)". Additionally, there is no singular inquiry method across scientific disciplines. Schwab clarified that one scientific inquiry could be the apex point for one discipline and the middle point for another. It also relies on the nature of the scientific disciplines.

Another inquiry bias is the individual habit of inquiry of the scientist. Schwab mentioned that very few scientists alter their propensity of inquiry in their scientific profession. He also added that the practices and the posture of the scientist are unchanging from scientific discipline to discipline and even by scientific generation to generation.

Schwab (1960) framed the inquiry practices through four reasonable ways: (a) the human has access to a limited number of inquiry patterns, as well as inquiry formulation capability; (b) differences in personal preferences about inquiry patterns could be another inquiry bias which could be noticeable in their academic field; (d) finally, there may be scientific discipline bias for executing inquiry.

Schawab discussed six decision points for practicing fruitful inquiry, the forms of principle for inquiry, criticism for the judgement of principle, reliability-validity, stable vs fluid enquiries, guidance, collection, interpretation, and the 0-point of decision (Schwab, 1960).

The Forms of Principle for Inquiry

Schwab (1960) considered principles as the ideas which encourage and instigate any planned activity; principles for inquiry do the same thing. Principles of inquiry might emerge from scientific doctrine which is championed by the scientist or the natural habit of the scientist for deter- mining the subject matter or the problems. Schwab also described a few signs about the principles of inquiry through binding and analyzing a subject matter that is suitable for inquiry.

Analytic function of principles consists in identifying the meaning-units or meaning-elements which are to be treated in inquiry into the subject-matter. Finally, the principles of inquiry restrict the form which knowledge of the subject will take by indicating how the data is to be interpreted.

Criteria for the Judgement of principle

There is a legitimate question about how scientific knowledge develops. Who decides if the scientific knowledge is part of the depository or not? Then the question comes about the judgement principles for scientific knowledge. Schwab (1960) discussed judgement principle for inquiry as a criterion. There is hesitation among the social-science based disciplines such as psychology and political science, about the variety of conceptions among the scholars. In addition, every field has some kind of recurring crises with new discovered phenomena. For instance, there is some level of efficacy challenges for existing principles as new sets of principles emerge or demand amendments of the existing ones.

Judgement principles for inquiry require scrutinized reports from the relevant scientific community who decide the discovered knowledge as part of the scientific discourse based on scientific evidence (Schwab, 1960). Besides this, the scientist has to prove how the discovered knowledge could be aligned with the existing scientific knowledge. Therefore, there could be necessary amendments in the existing knowledge of the disciplines or the extension of the existing knowledge. Schwab (1960) mentioned four judgement criteria- interconnectivity, adequacy, feasibility, and continuity.

1. Interconnectivity: Interconnectivity concerns the extensive domain of subject-matters subsumed by the proposed principle.

2. Adequacy: Adequacy concerns its intensive domain, the degree of complexity or "completeness" with which the principle subsumes the details of subject-matter.

3. Feasibility: Feasibility concerns the ease, economy, precision, and consistency with the data required the principle can be collected.

4. Continuity: Continuity concerns the ease or difficulty with the new principle can be made to contain the bodies of knowledge previously formulated in other sets of term (I.e. By translation or by subsumption as a special case).

Reliability-Validity

Reliability and validity are recognized as co-ordinate and complemental of scientific knowledge by the scientists. Reliability is concerned about the produced scientific knowledge and validity is concerned about the subject of the scientific knowledge. Therefore, the scientist is obliged to provide adequate evidence for the scientific claims accumulated from the executed inquiry. Besides this, the scientists need to represent as much of the extent and complexity of the subject as possible (Schwab, 1960).

Schwab (1960) defined reliability as free from vagueness and ambiguity. It also clearly distinguishes the limit of the subject-matter that emerged from the inquiry. On the other hand, validity is concerned about the richness and complexity of the subject-matter. Additionally, validity ensures the adequacy and interconnectivity of the scientific knowledge.

Traditionally, scientific knowledge is considered as permanent knowledge and it supposed to grow only by accretion. New scientific knowledge adds on existing scientific knowledge; Old scientific knowledge acts as the foundation for new knowledge. However, scientific knowledge develops as a separate new scientific concepts that accumulate over time.

Validity demands representative evidence which reflect adequate richness and complexity of the subject-matter. Therefore, although the data has enough reliability, it also demands adequate evidence about its valid scientific subject-matter.

Stable VS. Fluid Enquiries

Stable inquiry develops based on conceptual principles which collect through fluid inquiry. Schwab stated that stable inquiry principles adopt conceptual principles as matter of facts. In other words, researchers try to fill out the blanks of the existing knowledge rather than testing knowledge. Usually, the researchers uses principles as a means of inquiry. Besides this, the principles define the problems and guide the patterns of experiment. Fluid inquiry tests the existing scientific principles and discovers new principles and replaces the existing principles or extends the old principles.

Fluid inquiry is a mode of investigation which rests on conceptual innovation, proceeds through uncertainty and failure, and eventuates in knowledge which is contingent, dubitable, and hard to come by. (Schwab & Brandwein, 1962)

Guiding, Collecting, Interpreting

There are scientists who concern themselves primarily with the invention and proposal of principles. There are scientists who delight in the meticulous and careful accumulation of data for interpretation by others.

There are still other scientists who engage primarily in the work of review and monograph. The activities of review and monograph in the biological sciences are signs and sources of professional political power.

The task of monographer is to relate diverse researches. The conclusions of such researches are usually less than certain and often contradictory. Their apparatus of terms and techniques will often exhibit wide variability, in respect of generals as well as specifics. The integration of such diversity requires judgement of reliability and validity of numerous researches, and in the process of exercising that judgement a monographer has the chance to influence their future course of a field of inquiry and to affect individual careers for better or worse.

The O-Point of Decision

The enquirer eyes the subject-matter as known and as it might be known, and the disparity he sees there constitutes his starting point.

The second choice of starting point is familiar enough: not the subject-matter and the holes in the science of it, but techniques and instruments, intellectual or otherwise: path-coefficients, factor analysis, game theory, electroscopes, computers, tape recorders. The inquirer has his favored instrument and is master of it. Like a child with a hatchet, he looks for something to chop.

The third choice is neither hole in science nor instrument mastered, but virtuosity, *per se*. The enquirer believes he excels others in ingenuity, inventiveness or what not and looks for means to exhibit it. His starting point is anything or situation through which he can exhibit his skill. His relation to like-sexed peers is reminiscent of Don Giovanni's and worth investigating.

Inquiry in Science and Science Education

NSES (1996) pointed out that using inquiry in the science classroom to learn science, en- gage in many of the same activities and thinking processes, and expand human knowledge of the natural world as scientists do. Since the activities and thinking processes used by scientists are not always familiar to the educator seeking to introduce inquiry into the classroom, inquiry teaching has many facets. Therefore, students and teachers have to learn shoe the use inquiry to learn how to do science, learn about the nature of science and learn science content to follow the scientist and their scholarship (NRC, 2000).

Inquiry in education influences and changes both in theory and practice across scientific disciplines. Theoretical influence will require curriculum, instruction and rigorous professional development. On the other hand, practical aspects of inquiry will be impacted by teachers experience and practice. NRC (2000) mentioned that inquiry practice in the classroom can be in many forms— highly structured to open ended. However, the level of practice always designed by the teachers depends on their students level of practice always designed by the teachers depends on age of the students' level. As well as inquiry practice in science depends on students age and science topics.

Additionally, teachers can improve the inquiry level based on level of inquiry practiced and acquired scientific knowledge.

Although there might be significant differences between scientist and educator's practicing inquiry for the nature and depth of the content, as well as the inquiry in laboratory and the class- room, the teachers and students always try to use inquiry to learn to do science, learn science as content as final product.

The Nature of Human Inquiry

Human generate cognitive abilities through interacting with the environment by their senses. We encounter the world by observing, tactile, kinesthetic for gathering and analyzing data that are a basic requirement for inquiry. On the other hand, based on gathering data we develop hypothesis, generate ideas for tentative solution. Similarly, scientists use inquiry process, through more regimented and professional, way to study natural phenomena that differentiate the field of knowledge. *NSES* recommended teachers to build children's natural, human inquisitiveness to understand science as human endeavor.

Inquiry in the Science Classroom

One of the goals of *NSES* (1996) is inquiry for all students in all grade levels through it re- quires curriculum, instruction, teaching materials as well as teacher incentive preparation. NRC (2000) recommended an outline for introducing inquiry in the classroom by pointing out categories— a) exhibit curiosity, b) define questions from current knowledge, c) propose preliminary explanations or hypothesis, d) plan and conduct simple investigation, e) gather evidence from observation, f) explain based on evidence, consider other explanation, communication and test explanation.

***NSES* described what should inquiry look like in education**

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (NRC, 2000, p. 23).

"Inquiry" is a particular way of science teaching-learning for educators. However, *NSES* has defined "inquiry" as something more grounded, and pedagogical aspect is only one aspect. It emphasized the understanding of inquiry and the scientific knowledge development process together.

NSES included both content standards and inquiry standards. The purpose of the inquiry standards was to build student understanding of how they know what they know. The content standards also required students to understand inquiry to produce scientific knowledge (NRC, 2000).

NSES recommended development of inquiry in certain processes. In order to acquire new scientific knowledge, students should use their previous experiences for encountering their inquiry questions. Additionally, the students also practice inquiry to be competent with their new scientific knowledge (NRC, 2000).

Teachers should design and teach inquiry through activities to engage and practice the inquiry process. In other words, students should gain deep understanding of the inquiry characteristics by doing activities.

NSES recommended that teacher should introduce fundamental elements of inquiry to the students for their experience and understanding. They also should encourage reflective practice in science classrooms (NRC, 2000).

Learning through Inquiry and It's Implication for teaching

NSES described the essential features of classroom inquiry (NRC, 2000): (a) learners are engaged by scientifically oriented questions, (b) learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions, (c) learners formulate explanations from evidence to address scientifically oriented questions, (d) learners evaluate their explanations in light of alternative explanations, particularly those reflect- ing scientific understanding, (e) learners communicate and justify their proposed explanations.

Learners are engaged by scientifically oriented questions

Robust and faithful questions help students to accomplish successful inquiry. *NSES* (2000) suggested scientific questions should emphasize natural objects, organisms, and events; *NSES* content standards also connected these science concepts.The questions motivate students to get answers and that allows them to learn. The questions would come from students or be generated by the teachers based on the lesson plan topic study. Additionally, the teachers' role and skills are foremost important for integrating all of those sources for developing knowledge.

NSES recommended accessible and manageable questions for students (NRC, 2000). The questions could help the students to develop their knowledge and learn skills through accomplishing inquiry successfully. Therefore, there might be different levels of inquiry. It could be more open ended and complex to simple questions; The curriculum, instruction and teachers involvement is also important for making different level of questions and inquiry. However, *NSES* suggested that "why" and "how" oriented questions are efficient in the school science context for doing inquiry.

Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.

Science and scientists use empirical evidence for answering scientific questions. Scientists generate scientific evidence from their gathered data. Therefore, scientists prioritize the apt data from their experiment or phenomena for their evidence . The nature of the scientific experiment or levels of inquiry select the complexity for obtaining the data and evidence. For some cases, students design their experiments for different variables and gather their data. The evidence helps the students to answer their questions or generate further investigation.

Learners formulate explanations from evidence to address scientifically oriented questions.

Explanations are ways to learn about what is observed to what is already known. So, explanations go beyond current knowledge and propose some new understanding (p. 26). Both existing knowledge and new experiences are important for formulating explanations and generating new scientific knowledge. Compared to gathering evidence, formulating explanation is a path to explain the evidence based on the research questions. However, there could be a whole different explanation that could be compatible with the research questions. Therefore, though the research questions could lead the experiments, there is no confirmation about certain explanations. The explanations depend on various cognitive process based on their gathered evidences or go beyond the research questions.

Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.

Making connections between their self-developed results and existing scientific knowledge is essential for arguing alternative explanations. *NSES* recommended *alternative explanations* could be developed from student classroom dialogue, teacher provided evidence, or course based materials. The most prominent feature of scientific knowledge is evaluating existing knowledge, revise the scientific explanation, find out apparent biases and flows, and derive new explanation based on new evidences. Students have to be consistent with relying existing scientific knowledge for developing their new evidences.

Learners communicate and justify their proposed explanations.

The scientific knowledge requires replication by other scientists. Scientists share their research questions, procedures, proposed explanations and evidences with others. It helps other scientist to understand the new scientific knowledge and recognize their scientific achievements. *NSES* recommended that students should share their experimental findings with other classmates. Sharing the findings give students the opportunity to know and understand different scientific questions, observe different biases or flaws, get beyond existing scientific explanation and find new explanations like scientists.

The essential features are one of the ways to help the students to develop some particular scientific concepts and processes in order to learn coherent and deeper knowledge. The features introduce how to formulate scientific questions, generate evidences; evaluate evidences, propose and communicate explanations with the scientific community.

Levels of Inquiry

Classroom inquiry has five essential features as described in *Inquiry and the National Science Education Standards* (NRC, 2000). The essential features are : (a) learners engage in scientifically oriented questions, (b) learners give priority to evidence in responding question, (c) learners formulate explanations from evidence, (d) learners connect explanations to scientific knowledge, (e) learners communicate and justify explanations.

Lederman (2003) pointed out three different components of inquiry- as a teaching strategy, a set of student skills (develop individual skills and forming logical conclusions), knowledge (Develop understanding) about inquiry.

Banchi and Bell (2008) presented the inquiry continuum with low-level structured to high level open inquiry. The continuum created based on how much information is provided to stu- dents and how much guidance will provide as the teacher (Banchi and Bell, 2008; Bell, Smetana, and Binns, 2005; Herron, 1971; Schwab 1962). In other words, the continuum give the opportunity to students the guiding question, procedure, and expected results to create their own inquiry. They incorporated four-level continuum-conformation, structured, guided, open.

Confirmation Inquiry

Teachers provide the students advance the question, procedure (method), and the results for the inquiry. Usually, confirmation inquiry reinforces the student newly introduced idea or rehearsal a specific inquiry for mastering scientific skill or practical knowledge of conducting investigation (Banchi & Bell, 2008).

Structured Inquiry

Though the question and the procedure of the inquiry provide in advance, however, student have to bring about supportive explanation from their own collected data (Banchi & Bell, 2008).

Guided Inquiry

Teacher provides students only the research question for their study, and students design their procedure (method) to test their question and they answer and explain their research question from their resulting. When students have a lot of opportunities to learn and practice different ways to plan experiments and collect data then guided inquiry is successful than others (Banchi & Bell, 2008).

Open Inquiry

Open Inquiry is the highest level of inquiry. Open inquiry provides the students the purest opportunities to act like scientists; the students derive questions, design and carry out investigations, and communicate their results with others. It requires from students the maxim scientific reasoning and apex cognitive demand. Students at the fourth- and fifth-grade levels can be able to successfully conduct open inquiries with ample experience at the first three levels of inquiry (Banchi & Bell, 2008).

Banchi & Bell (2008) recommended students for conducting a open inquiries when they can demonstrate that they can successfully design and carry out investigations when provided with the question. In other words, students can able to record and analyze data from their designed investigation as well as draw conclusions from their evidence they have collected.

A Framework for K-12 Science Education

A Framework for K-12 Science Education was the first step for developing new K-12 science standards. The framework was developed by the National Research Council (NRC) and Achieve, Inc. took the lead to develop the Next Generation Science Standards. Although *K-12 science content standards* were developed in the mid-1990s, this new framework is an initiatives to but- tress science education. This framework is a compelling effort in content-standards experiences and growing research on science teaching/learning. The framework developed based on the previous science education efforts; in other words, the framework is a gradual effort of *Science for All Americans (1985), Project 2061 (1989), Benchmarks for Science Literacy (1993), National Science Education Standards (1996),* and *Inquiry and National Science Education Standards (2000).* The *framework* is the first step of the science standards development process. *The*

Opportunity Equation, written by Institute for Advanced Study, recommended developing a common set of science standards for the whole nation.

The *framework* outlined science teaching-learning based on three dimensions: (1) science and engineering practices, (2) crosscutting concepts that unify the study of science and engineer- ing through common application across fields, and (3) core ideas across four disciplinary areas: physical sciences; life sciences; earth and space sciences; and engineering, technology, and ap- plications of science. Throughout, the *framework* focused on the dimensions of how curriculum and instruction should be integrated vertically and horizontally aligned with science, engineer- ing, technology and mathematics within a school year and across school years (NRC, 2011). The *framework* also emphasized that students should engage in scientific inquiry and engineering design.

The *framework* incorporated *'practice'* instead of *'skills'* from previous *NSES* documents. The major goal of the practices is to investigate and build models and theories about the world like scientists. The "practices" underscored engaging in scientific inquiry which required both scientific knowledge and skills.

The *framework* described science education goals as the enrichment students' scientific habits of mind, engagement with efficient scientific inquiry, and teaching the students how to contemplate in the scientific context. There are arguments about the importance and emphasis on science content knowledge versus scientific practices in

K-12 science education. However, con- fined focus on content could cause accumulation of isolated scientific facts and ingenious conceptions of scientific inquiry.

Since the NSES did not articulate inquiry with any specific framework, there have been variations in inquiry practices among the educators and science education community. The new science framework designed the systematic inquiry practices in a regimented way. Science and engineering practices considered not only science but also considered cognitive, social, and physical practices through inquiry.

The framework mentioned that science teaching should set the opportunity for the students to engage, learn, and practice scientific concepts rather than get just second hand experiences. It also added that students cannot comprehend scientific knowledge without experiencing and practicing it (p.30).

The framework also mentioned that science and engineering practices will help the students to see how scientific knowledge develops, how engineers work, and how science and engineering work together. It also will help the students to understand how the practices are linked with crosscutting concepts and disciplinary core ideas of science and engineering. Additionally, the practices of science and engineering will help grow the students' interest and inspire them to follow up with their schooling. Moreover, it will also help them endeavor in how scientists and engineers are contributing and effecting modern society. This will help the students to understand contemporary scientific, social, and engineering issues and allow them to take their position.

The *framework* mentioned three spheres of activity that scientists and engineers practices: investigation, evaluation, and developing explanations and solutions. The first sphere is investigation and empirical inquiry. The *framework* also defined eight practices: (1) Asking questions (for science) and defining problems (for engineering), (2) Developing and using models, (3) Planning and carrying out investigations, (4) Analyzing and interpreting data, (5) Using mathematics and computational thinking, (6) Constructing explanations (for science) and developing designs (for engineering), (7) Engaging in argument from evidence, and (8) Obtaining, evaluating and communicating information.

A framework for K-12 Science Education describes eight practices related to both scientific inquiry and engineering design. Inquiry and engineering design share six practices out of eight and two — (1) asking questions and defining problems, (2) constructing explanations and de- signing solutions — describe practices quite different from one another. Additionally, some of the same practices are used for different purposes. For instance, scientists and engineers both use models for complex systems. Scientist use models to understand how nature works. On the other hand, engineers use models to understand how products or built systems work. Scientists and engineers try to apply their best available tools for their investigation or problem solving. Now-a- days, computer or computer simulated tools are the best choice for both scientists and engineers.

In sphere one, scientists and engineers work for two different goals for their own proposes. Scientists start with asking about a natural phenomenon —"why" or "what" are the causes. On the other hand, engineers ask questions to define engineering problems. Scientists observe the natural phenomena, determine what needs to be measured, plan for an experiment which tends to collect data, select a data collection method, and build an appropriate measurement instrument. Whereas, engineers engage themselves to develop a design to test their problem. However, scientists and engineers vary their investigations and designs based on their discipline or field.

The second sphere is developing explanations and solutions. Like the previous sphere, scientists propose explanations to a theory or create a new model based on existing theories and models. On the other hand, engineers create a design as their practice. Design development could be development of either a simulation or creating infrastructure or both. However, both scientists and engineers use models to predict the behavior of the system. They collect data from their model and calculate it to find a prediction.

The third sphere is the practice of evaluation. This sphere works as an interactive process between the investigation and design spheres. In other words, there is always critical thinking between investigation and models to come up with a conclusion or solution. The argumentation and critical thinking helps to establish or modify a proposed model or open doors for further experimentation. Both scientist and engineers use their evidence to find weaknesses or limitations in their argument for pursuing improvement in their explanation or design.

Asking Questions and Defining Problems

"Questions are the engine that drive science and engineering (p.54)." Asking questions and defining problems is the first step to practice science and engineering, though their purpose may be different. Asking questions helps students to develop and practice scientific habits of mind (p. 54). Since science and engineering have different purposes, there are different ways for developing question or identifying problems. However, they could start by simple observation of natural phenomena or by inspirations from what models or theories have predicted. Usually, scientists start with a problem about a phenomenon by asking 'what', 'why' or 'how'.

Engineers develop their questions by asking probing questions from an engineering problem. Their purpose in developing questions for identifying problems is to come up with purposeful solutions; the solutions try to meet the design criteria. The *framework* recommended that students at any grade level should be able to ask questions through out their different levels. The students should also be able to share each other's queries about the natural phenomenon or the engineering problems, or even from their models or scientific investigation.

David (2013) described the common misconceptions about questioning and defining problems: "Beginning designers tend to treat design challenges as well-defined problems that they can immediately solve with a single correct answer rather than delaying their design decisions until they understand". The *framework* also emphasized the progression of asking questions and defining problems across grade levels. It recommended asking questions for natural and human- built worlds. Distinguishing scientific questions from non-scientific questions, formulating and refining questions, elaboration, and gather supportive evidence for scientific argumentation are also challenges to apply in classrooms. Engaging efficient engineering problem requires appropriate nourishment through school years. The *framework* recommended that defining engineering problems elicits the ideas that lead to finding the constraints and specific solutions for progression.

Developing and Using Models

There are two kinds of models used by scientists: mental models and conceptual models of phenomena. The purposes of these models are quite opposite and complementary. Mental models are used as a tool for thinking, predicting, and making sense of experiences. On the other hand, conceptual models are analogues to an explicit representation of phenomena. Conceptual models provide opportunities to scientists and engineers to understand and visualize phenomena which help them to investigate or develop a possible solution to a design problem.

The *framework* (2012) recommended that a simple conceptual model might use diagrams, physical replicas, mathematical representations, analogues, and computer simulations. However, there could be some variation in computational models. The variations might depend on model approximations and assumptions to validate their application and prediction power. The limitations are important in recognizing a model's predictive and validation power.

Although conceptual models are external articulations of human concepts, they represent the internal mental senses of scientists and engineers. Additionally, conceptual models help to understand and revise mental models. In other words, mental models provide the understanding about the scientific concepts and reasoning.

Scientist and engineers use models differently based on the purpose. Scientists use models to understand and intuit the system, generate their own questions and answers, and communicate their ideas with others. Moreover, mathematical computation could be another reason for scientist to use models; it helps them to calculate their assumptions.

Computer simulations are developed from the complex conceptual system and mathematical system. Computer simulation helps scientists to predict intractable behavior in the system. On the other hand, engineers use models to analyze their existing systems. The models help them to find the flaws from a system and make a tentative solution. Engineers find problems and solve them through engineering design. Different prototypes give them different opportunities. Specially, computer simulations help the engineers to encode for realizing and testing engineer designs.

Planning and Carrying Out Investigations

Scientists and engineers investigate and observe the world with essentially two goals: (1) to systematically describe the world and (2) to develop and test theories and explanations of how the world works. In the first, careful observation and description often lead to identification of features that need to be explained or questions that need to be explored.

The second goal requires investigations to test explanatory models of the world and their predictions and whether the inferences suggested by these models are supported by data. Planning and designing such investigations require the ability to design experimental or observational inquiries that are appropriate to answering the question being asked or testing a hypothesis that has been formed. This process begins by identifying the relevant variables and considering how they might be observed, measured, and controlled (constrained by the experimental design to take particular values).

Analyzing and Interpreting Data

Data provide certain patterns and relationships to the information that help to inform decisions. Scientists usually organize and interpret their data through tabulating, graphing, or statistical analysis to answer their research questions. The analysis helps them to bring out meaning and find some evidence. The ultimate goal is to communicate their evidence based on their data.

On the other hand, engineers make decision based on the evidence to modify their design. However, engineers collect and analyze their data based on model, prototype, or simulation. After collecting their data they use mathematical analysis to analyze it. The analyzed data provide them evidence; the evidence helps them to predict or assess their design performance and to define or clarify design problems.

Scientists and engineers use spreadsheets and databases to organize their data. Different kinds of tables, graphs, and pictures present the relationships between different kinds of analyzed data. Tables help to make convenient accessible forms of data, graphs help to visualize the data which makes the information more accessible and makes decisions based on the evidence easier; finally, mathematics helps to make a reasonable analysis to the data. Computer based simulation has provide the opportunity to visualize and understand all these data, analysis and presentation much easier and accessible.

Using Mathematics and Computational Thinking

Mathematics and computational tools are central to science and engineering. (P. 64). Science and engineering adopted different computational theories and computational technologies over time. Computational technologies help to manage data sets for finding certain patterns to correlate some relationship. They also demand to find new mathematical models for working on new phenomena or problems. Although scientists' and engineers' work is visible, mathematics and computational tools work in the foundational level of the decisions.

Mathematics and computational tools work complementarily. The power of mathematics is visible in computational tools which would not be possible without it. They both help to understand different dynamics of phenomena or complexity in a design. They also help to find results based on calculation or simulation to find a pattern. Now-a-days, engineers use computer simulations to find real time challenges, and design performances.

Constructing Explanations and Designing Solutions

Scientists develop new theories based on their new information or existing information to understand the natural world or a particular phenomenon, or to predict a future event or to make an inference about a past events. Theories are not mere guesses, and they are especially valued because they provide explanations for multiple instances. (P.67). Scientific explanations account for scientific theory with specific observations or phenomena.

Engaging in Argument from Evidence

Scientists and engineers use reasoning and argumentation for developing new theories, and for explaining natural phenomena, solutions for technological problems, or novel interpretations of old data. (P.71). Usually, scientists make claims about the natural world based on the reasoning process.

Obtaining, Evaluating and Communicating

To become science or engineering literate one of the required competencies is to prepare their literature to be accessible to others. Although scientists and engineers work and accomplish their challenges in laboratories, they prepare their findings and communicate them with the scientific and engineering discourse groups. Therefore, using words, diagrams, charts, graphs, images, symbols, and mathematics are other challenges for them.

The *framework* (2012) mentioned that scientists and engineers spend at least half of their time reading, interpreting, and practicing test. Additionally, they also spend their time reading about others' accomplishments through reading different journals and articles.

Following the engineers and scientists, it is necessary for the K-12 student to accomplish these skills to become scientists or engineers. The *framework* (2012) described the reading challenges that become important in scientific literature. Academic vocabularies are the greatest challenges for the readers because they are totally unfamiliar and require intense understanding. Therefore, most of them are used in scientific and engineering discourse groups. That's why they are inaccessible to regular people. Besides these, passive voice and complex sentence structure could also be a challenging part of their reading problem.

The second challenge mentioned is extracting information from the text which requires practice understanding scientific words or clauses and their contexts.

The third challenge is that scientific literature uses combinations of words, diagrams, charts, symbols, and mathematics to communicate with discourse groups. Therefore, students need special skills to read, understand and to interpret modes for extracting meaning from scientific literature.

The other two communication skills are written and spoken skills. Verbal communication skills are required because scientists and engineers need to present, describe, and argue their findings orally. The verbal communication skill is a real time challenge for scientists in international or multi-lingual contexts.

Writing is the most challenging and important communication tool for scientist and engineers. Writing exists as a document that prevails over generation or centuries as scientific evidence. Therefore, to communicate with the scientific community, students require this inevitable skill.

Inquiry Based Instruction

Strengthening Science Education: The Power of More Time to Deepen Inquiry and Engagement suggested strengthening STEM education whether separately or in integrated ways. *The National Center on Time & Learning (NCTL)* recommended improving science instruction. *The National Assessment of Educational Progress*

(NAEP), Trends in International Mathematics and Science Study (TIMSS), and the Program for International Students Assessment (PISA) condemned poor science instruction for STEM graduate disciplines and STEM jobs (Bybee, 2013).

NCTL reported that No Child Left Behind legislation put behind elementary science instruction (p.47). *Taking Science to School* urges increasing student engagement to become competent in science, which required more teacher professional development for enriching scientific knowledge and becoming adept in scientific practice. It will help the teachers to engage students and improve instruction. The report also recommended increasing science teaching hours to make the students more competent in STEM education. Bybee recommended that the schools should incorporate more hands-on activities and encouraged more scientific discourse; implemented scientific strategies to encounter deficiencies in reading levels, contexts, and vocabulary; embellished core content with connections to careers; and enhanced school programs with experiences in informal settings.

Inquiry-based science instruction has been using the instructional part of the science inquiry method. Minner, Levy and Century (2009) have done research about impact of inquiry-based instruction in science education from 1984 to 2002. They analyzed 138 studies about inquiry based instruction and found that there is a clear indication of positive achievement of science education by using inquiry based instruction. Their analysis showed that inquiry-based instruction stressed on students' active thinking and drawing conclusion based on their investigated data. Additionally, Actively engaged students can increase conceptual understanding through the scientific learning process than passive learning process.

There is no concrete information about the first inauguration of inquiry-based instruction. How- ever, the nature of learning and teaching give the emergence of the type of instruction in a certain discipline. Cakir (2008) pointed out that constructivism-based teaching-learning materials induced inquiry- based and hands-on based activities for exploring science concept.

Linking Inquiry Based Instruction and 21st Century Skills

Bybee (2009) emphasized 21st century skills as explicit learning outcomes. See the following chart.

Table 2.1

Linking Inquiry Based Instruction and 21st Century Skills

21st Century Skills	**Inquiry based Instructional Model**
Adaptability	Adequate Evidence
Complex-Communication	Some Evidence Based on Argumentation
Non-Routine Problem Solving	Strong Evidence Based on Scientific Reasoning
Self-Management/ Self Development	Strong Evidence Based on Attitudes Toward and Interest in Science
Systems Thinking	Strong Evidence Based on Mastery of Scientific Knowledge

Successful K-12 STEM Education and *Monitoring Progress Toward Successful K-12 STEM Education: A National Advancing* have identified effective criteria for STEM schools and prog*rams. The reports analyzed science and mathematics components for STEM schools. It focused on students outcomes, STEM focus, and instruction and practices. The reports identified key elements of effective STEM instruction foundations: (1) a coherent set of standards and curriculum, (2) Teachers with high capacity to teach this discipline, (3) a supportive system of assessment and accountability, (4) adequate instructional time, and, (5) equal access to high-quality STEM learning opportunities.*

Science, Technology, Engineering and Mathematics (STEM) Education

> "One of the things that I've been focused on as President is how we create an all-hands-on-deck approach to science, technology, engineering, and math. We need to make this a priority to train an army of new teachers in these subject areas, and to make sure that all of us as a country are lifting up these subjects for the respect that they deserve." President Barack Obama (White House, 2013)

The National Science Foundation (NSF) originated 'STEM' in the 1990s at as an acronym for science, technology, engineering, and mathematics. There were also a few other acronyms which emerged at the same time: SMET or METS. Though there was some confusion with stem cell research, STEM was initiated by NSF and in their different education programs.

Although there is not a national definition of STEM education, several groups have tried to capture the generalized idea. The meaning or significance of ‘STEM’ was not clear and distinct. Though it refers to four disciplines sometimes the meaning or significance varied based on the context, use and perspectives. Therefore, it may emphasize one, two or more disciplines from STEM separately or in consolidated ways. The New York STEM Education Collaborative in conjunction with the National STEM Collaborative came up with one of the first broadly circulated definitions which stated:

> STEM Education refers to utilizing the Content Standards in the teaching and learning of the Science, Technology Education, Engineering and Mathematics(STEM) disciplines, in an innovative, integrated, collaborative, and applied fashion to a level of challenge sufficient for college and/ or career readiness (New York State STEM Education Collaborative, 2009, pp.0).

Another widely circulated definition comes from Tsupros, Kohler, and Hallinen (2009) in which they stated:

> STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (pp.1)

The National Science Teachers Association (NSTA) states that Science, Technology, Engineering and Mathematics (STEM) should not be another discipline or subject area, but rather an instructional strategy to help develop the innovators of the future (Gerlach, 2012).

Purpose of STEM Education

Bybee (2013) mentioned that the term *purpose* refers to a number of goals that STEM education should achieve, such as STEM literacy for all learners. The purpose of the STEM education is to practice the STEM disciplines in situations students encounter in life and allow all students to become competent to learn and apply basic content and skills. STEM literacy refers to specific knowledge, attitudes, and skills to identify questions and problems in life situations for every individual. It explicates the natural and designed world to come up with a conclusion about STEM-related issues based on their evidence.

Another purpose of STEM education is to understand characteristics of STEM disciplines as forms of human knowledge, inquiry, and design. STEM education also informs the students how STEM disciplines are shaping our material, intellectual, and cultural environments. Additionally, STEM education engages students to STEM-related issues as a constructive, concerned and reflective citizen through introducing and practicing science, technology, engineering and mathematics ideas (Bybee, 2013).

Importance of STEM Education

Secretary of Education Arne Duncan Stated:

> Frequently when I talk with teachers, they ask, “Why is the department so focused on the STEM subjects: science, technology, engineering, and mathematics?” I tell them that the world is changing and that scientific knowledge and skills are essential for success in the knowledge economy. (Bybee, 2013)

Bybee (2013) mentioned that STEM education should expedite to develop STEM-literate society, excel the workforce with 21st century competencies, and focus on innovation with advanced research.

Focus on the STEM subjects-science, technology, engineering, and mathematics. STEM edu- cation and identify justification for a focus in a knowledge economy. Secretary Duncan provides one reason about why we need STEM subjects for success in a knowledge economy. He added that STEM subjects will improve student learning, job demands, international competitiveness, and a society that can respond to contemporary STEM-related issues.

21st-Century Workforce and STEM Education

Dr. Alan Greenspan mentioned that

> In today’s economy, it is becoming evident that a significant upgrading or

activation of underutilized intellectual skills will be necessary to effectively engage the newer technologies (Greenspan, 2000).

Greenspan identified several important points for reform of STEM education which emphasized "intellectual skills" as an economic justification. Bybee (2009) mentioned that 21st century skills are aligned with scientific inquiry and engineering design. Bybee (2013) interpreted the ideas that there is a covert goal of today's education which should emphasize 'technology' to prioritize globalization and STEM education.

Changing Demands for Intellectual Skills

Just more than a century ago, many nations faced a period of substantial social change. The industrial revolution presented new demands on the intellectual skills of workers; they had to develop the cognitive skills to operate equipment in factories, mange production lines, and di- rect emerging transportation and communications systems. In that era, the equivalent of a high school education became a requirement for workers in many countries.

The 20th century was a period of significant scientific advances and technological innovations, both of which contributed to dramatic social progress. As a nation's economy advanced, the requirements for skilled workers increased, especially the need for intellectual skills, including those often associated with science, technology, engineering and mathematics.

By 21st-century standards, the intellectual skills required in the early 20th century were low. With time, nations realized the economic value of creative ideas and efficient means for the production and delivery of goods and services. As the 20th century progressed, job requirements for the workforce increased to levels beyond a high school education. Taking this general observation to the workforce increased to levels beyond a high school education. In specific observation, one would have to note the combined role of science, technology, engineering, and mathematics as a driving force of economic change and the steady shift in requirements for entry into the workforce, especially in developed countries. The changes just described suggest a fundamental place for science, technology, engineering, and mathematics in our economy and by ex- tension, in our education programs. The next section address the connections between 21st-century skills and STEM education.

Global Economic Competitiveness

The content and abilities of high-quality STEM education have clear and compelling connections to the goal of developing a 21st-century workforce and sustaining our global competitive- ness. Bybee (2013) recommended that to sustain the position of the United States as a global competitor, our nation needs a vision, a first tactical response, and a long-term strategic plan that outlines a decade of actions for reforming STEM education. Although the need to change seems evident, the changes specially implied for K-12 STEM education must be clarified and ad- dressed. The ability to address these changes presents one of the challenges for state, district, and school leaders.

Educating and Employing for a Brighter Economic Future:

A clear and compelling argument for changes in K-12 science and mathematics education is that the United States could remain prosperous in the 21st century. K-12 science and mathematics education focused on *teachers* and the *students* teaching-learning. Bybee (2013) recommended the following targets for achieving a vibrant economy in the 21st century: (1) annually recruit 10,000 science and mathematics teachers by awarding them four-years scholarship, (2) strengthen the skills of 250,000 teachers through summer institutes, master's programs, and Advanced Placement (AP) and International Baccalaureate (IB) training programs, (3) provide K-12 curriculum materials modeled on world-class standards, (4) enlarge the pipeline of students who are prepared to enter college and graduate with a degree in science, engineering, or mathematics, (5) provide intensive learning experiences through statewide specially high schools, and (6) use inquiry-based learning to stimulate student interest and achievement in science, technology, engineering, and mathematics.

K-12 education's emphasis should be on those students destined for careers in science, engineering, and mathematics, as these disciplines are perceived as fundamental for technological innovation and economic productivity. Interactive Educational Systems

Design (IESD) identified three most significant challenges for STEM education: low number of qualified STEM teachers, insufficient professional development for STEM teachers, and Insufficient funding specially designated for STEM. (Bybee, 2013)

Elementary School Teachers and the Crisis in Science, Technology, Engineering and Math Education has recommended five specific goals:

> (1) Increase the selectivity of programs that prepare teachers for elementary grades, (2) Implement teacher compensation policies, including performance-based pay, that changes elementary teaching a more attractive career for college graduates and career changers with strong STEM backgrounds, (3) include more mathematics and science content and pedagogy in schools of education, (4) Require candidates to pass mathematics and science subjections of licensure exams, (5) explore innovative staffing models that extend the reach of elementary-level teachers with an affinity for mathematics and science and demonstrated effectiveness in teaching them (Bybee, 2013).

STEM-Literate Society

‘Defining scope of the problem of “lack of education” must begin with the *objectives* of education which is to equip people with range of competencies (which include both cognitive and non-cognitive skills, knowledge and attitudes) necessary to lead productive, fulfilling lives fully integrated into their societies and communities.

This quote introduces competencies to describe a range knowledge, attitudes, and skills that individuals should develop. It does not, however, elaborate on specific knowledge, attitudes, or skills; the latter is one challenges of STEM education.

K-12 education should contribute to individuals' life and work as citizens. Education in the STEM disciplines also should include the application of these knowledge, skills, and abilities to life situations in STEM-related categories such as health choices, environmental quality and re- source use. Future citizens need educational experiences that transcend the traditional boundaries of science, technology, engineering and mathematics discipline.

Public Understanding of STEM Education

The entertainment and Media Communications Institute (E&MCI) reported a survey that examined the understanding and perception of the acronym *STEM* in 2012. The survey results indicated that 86% of the respondents were not familiar with the acronym STEM (E&MCI 2010). Bybee (2013) mentioned about the results that may be a concern for those entrusted does not convey a meaning to those beyond the policy makers and educators who are already involved with STEM education.

Historian Lawrence Cremin provides key point for STEM education: 'How, then do we achieve an appropriate balance between the demands of individuality and the demands of community? He added that proper education of the pubic and indeed the proper creation of "publics" will to go forward the society. He emphasized anew a great public dialogue about education that would be the most important to be raised a STEM-literate society.

STEM for Excel Scientific and Engineering Innovation

PCAST (2012) released the report *Engage to Excel: Producing One Million Additional College Graduates With Degrees in Science, Technology, Engineering, and Mathematics.* Base on the projected need for STEM professionals, the report recommends strategies for improving STEM student recruitment and retention for the first two years of postsecondary education. The report three imperatives establish a foundation for excel science and engineering innovation: improve the first two years of STEM education in college; provide all students with the tools to excel, diverse pathways to STEM degrees.

PCAST (2012) report presents the additional recommendations for excel science and engineering innovation. PCAST suggested catalyzing widespread adoption of empirically validated teaching practices, advocating and providing support for replacing standard laboratory courses with discovery-based research courses, launching a national experiment to post secondary mathematics education to address the math preparation gap. Additionally, PCAST encouraged partnership among stakeholders to diversify pathways to STEM careers, create a Presidential Council on STEM education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education.

National Governors Association (NGA) has STEM two goals: increase the proficiency of all students in STEM, and increase the number of students who pursue advanced studies and careers. In other words, the governors' goals are STEM occupations are among the highest-paying, faster-growing and most essential jobs for economic growth and innovation.

Role of teachers and Administrator in STEM Education

The STEM education and leadership program at Illinois State University conducted a survey of 200 teachers and administrators. The survey was conducted to answer two questions: (1) Do administrators and STEM teachers have a basic understanding of STEM education? (2) What do administrators and STEM teachers believe about STEM education? The survey found that STEM education is not widely well understood, less than half of administrator understood STEM education even though they in STEM disciplines indicated varied levels of understanding of STEM education. Additionally, it also found that there is not a clear vision of STEM education even among those who support and teach STEM.

STEM Education and 21st Century Skills

"Pathways to Prosperity" report by Harvard Graduate School of Education recommended for more demanding labor market to the need for broader and deep skills and insights from glob- al perspective on education reform. *Pathways to Prosperity* places considerable emphasis on the need to close the continually widening gap between

demands of a 21st century labor market and the interests and aspirations of 21st century youth, especially minorities.

Several of the proposals in this report rest on the case that students cannot see connections between school programs and opportunities in the labor market. While avoiding explicit tracking, the report recommends developing connections between learning and work beginning in high school. Work-based learning and career and technical education (CTE) programs are the pathways to prosperity that schools, especially high schools, should implement. Such programs experiences that would best position them for future careers.

Developing capacities such as intellectual skills, cognitive abilities, scientific reasoning, and problem solving- in short, a deep technical workforce. Such abilities should be fundamental as we consider STEM programs, teacher education, and professional development. Unfortunately, the development of cognitive abilities is often assumed to be either a frivolous embellishment or a collateral outcome that occurs concomitantly with an education filled with the memorization of meaningless information. Developing the mental process of scientific inquiry and engineering design, for example, is the direct outcome of engaging students in appropriate experiences that require the practice and application of such cognitive abilities. STEM educators know how to design programs that provide students opportunities to achieve these aims while developing a deep and rich understanding basic scientific, technological, engineering, and mathematical idea.

STEM Education Reform

The STEM reform movement has informed practices of teaching STEM content for both the Core Curriculum State Standards (CCSS ELA and Math) and the Next Generation Science Standards (NGSS) as guided by the skills necessary for participating in the 21st century. The STEM based reform movement will require over one hundred thousand newly trained teachers in the next decade (PCAST 2010).

National policy calls for STEM oriented teacher professional development for achieving the STEM trained competent teachers (Bybee, 2012; Davis, 2003; Tsai, 2006). Professional development in STEM will provide an opportunity for pre-service and practicing teachers to understand how to integrate STEM subjects and associated inquiry based practices in to classroom instruction (NRC, 2000).

The professional literatures demonstrate some success with inquiry based STEM reform. In one example, Adamson et al. (2003) have demonstrated that a pre-service teacher preparation program that was completely revised through STEM practices resulted in a positive influence of inquiry based teaching practices used in the classroom for the students who became secondary school teachers. Nadelson et al. (2013) found that elementary teachers informed STEM based practices in their classrooms due to their hands-on interaction with students and inquiry based curricular preparation training.

Although the research shows some improvement in classroom practice from STEM based inquiry training, there is still a need to understand the connection of training to actual classroom practice. Nadelson, L. S. et al (2013) warned about eradicating STEM-related misconceptions through appropriate early STEM professional development to teachers. Ginns and Watters (1995) discuss the importance of accurate science concepts and related effective strategies for pre-service education programs. Nadelson (2009) reported challenges, especially related to students' misconceptions of the nature of science, and ideas for curricular support when implementing inquiry based curriculum. He also concluded that the greatest obstacles to inquiry based instruction were effectiveness of inquiry instruction and students prior knowledge.

If we want students to learn how to apply knowledge, their educational experiences must involve them in both learning the knowledge of STEM disciplines and reacting to situations that require them to apply that knowledge in context appropriate to their age and stage of development. Additionally, activities in science,, technology, engineering, and mathematics lessons and courses provide many opportunities to develop the skills needed for a deep technical workforce.

21st Century Skills

National Research Council published couple of important documents based on 21st Century Skills and science education, specially "Exploring The Intersection of Science Education and 21st Century Skills," "Research on Future Skill Demands'" Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century" and "Rising Above the Gathering Storm: Emerging and Employing America for Brighter

Economic Future". These documents explored the trend and future of the American workforce and the role of science education.

'Exploring The Intersection of Science Education and 21st Century Skills' is a summary of a workshop report on science education and development of 21st century skills by the National Research Council (NRC, 2010). Adaptability, complex communication skills and the ability to solve nonroutines problems have been considered as "21st century skills" (Levy and Murnane, 2004; National Research Council, 2008a).. However, Eisenkraft (2007) addressed five 21st century skills- adaptability, complex communication/social skills, nonrotuine problem-solving skills, self-management/self development skills, and system thinking (NRC, 2010).

Organization for Economic Cooperation and Development (OECD) has identified the following as 21st century skills and competencies- creativity/innovation, critical thinking, problem solving, decision making, communication , collaboration, information literacy, research and inquiry, media literacy, digital citizenship, information and communications technology operations and concepts, flexibility and adapt- ability, initiative and self-direction, productivity, leadership and responsibility (NRC, 2012).

Levy and Murnane added that nonroutine problem-solving skills and complex communication and social skills are also effective for professional jobs. Additionally, adaptability, self-management/ self- development, and systems thinking are also important in the rapidly growing sector of "knowledge work" (NRC, 2010). In this workshop they also explored the intersection of Science Standards sand 21st century skills- overlapping areas, unique domain-specific aspects and practices of science.

Schunn(2009) described science as inquiry and science and technology are most relevant to 21st century skills. Schunn explained that communication skills, planning and selecting appropriate evidence are mentioned in the science as inquiry standard. The science and technology category includes techno- logical design, which involves systems thinking and nonroutine problem solving (NRC, 2010).

Dede (2009) argued that 21st century skills are different than 20th century skills. He pointed out that skills are different based on the emergence of sophisticated information and communication technology. Levy and Murmane (2004) mentioned the fundamental 21st century knowledge and skills emphasizing on expert thinking and complex communication.

Lai and Viering (2012) mentioned critical thinking, creativity, collaboration, metacognition, and motivation as 21st century skills. They also suggested several questions for justifying the skills- “how do researchers define the skills, how are the skills related to one another theoretically and empirically and how do the researchers traditionally measure them”.

21st-Century Workforce Skills

In 2007, the National Academics held workshops that identified five broad skills that accommodated a range of jobs, from low-skill, low-wage service to high-wage, high-skill professional work. Individuals can develop these broad skills in STEM classrooms and programs, as well in other settings (NRC, 2008; 2010; Levy and Murnane 2004).

Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century (NRC, 2012) reveal 21st-century skills as a mixture of cognitive skills, personal motivation, conceptual knowledge. Many of these skills and abilities can be develop in STEM programs that include scientific inquiry, technological innovation, and mathematical computation. It should be made clear that STEM education cannot, and probably should not assume sole and exclusive responsibility for developing 21st-century skills.

Research indicates that individuals learn and apply broad 21st-century skills within the con- text of specific bodies of knowledge (NRC, 2008; 2010; Levy and Murnane 2004). At work, development of these skills is intertwined with development of technical content knowledge. Similarly, in STEM education, students may develop cognitive development skills while engaged in the study of specific STEM-related social or global situations. The following discussion presents five skill sets important for 21st century. Those skills sets include adaptability, complex communications, non-routine problem solving, self-management, and system thinking (NRC, 2010).

The 21st century skills are a cluster of personal, interpersonal or technical abilities and skills which reflects cognitive and conceptual knowledge as well as skills.

Adaptability

Adaptability requires potentiality and readiness for certain jobs which required to coping with cutting-edge tasks, undetermined and rapidly altered conditions. It also includes both cognitive and psychomotor skills that are conducive for responding efficiently in a imminent situations and responding based on their learning with essential tasks, technology and process. Adaptability helps to overcome work pressure, work with different personalities, adapt with different learning styles and cultures. Additionally, psychomotor adaptability helps to adapt with various physical work environments. (Houston 2007; Pulakos, Arad, Donnovan, and Plamond 2000).

Complex communication and social skills

Complex communication works with both verbal and nonverbal information. It processes and interprets words, sounds and images and shares understanding for persuasion, negotiation, instruction and for services. Skilled communication helps people to interact within the team and serve others (Peterson et al. 1999).

Non-routine problem-solving skills

Problem-solving skills examine required information for diagnosis of a problem. It starts with narrowing information for identifying certain patterns. On the other hand, solutions requires certain knowledge and skills of how to connect with concepts as well as meta-cognition ability (Levy and Murnane 2004). Additionally, Nonroutine problem solving demands new information, integrated with problems and existing knowledge which helps to find out certain solutions. (Huston 2007).

Self-management and self-development

Self or individual skills help to work autonomously. However, it comes with a few responsibilities such as working virtually as a team member, accumulating information on demand and certain skills required to analyze and find out certain solution as part of a team or individual need. At the same time, information gathering, processing and findings depends on individual motivation, monitoring and self-management (Houston 2007).

System Thinking

A system always works with entire components of the system as a whole. As well, system thinking skill always tries to develop a big picture of a work. It helps to perceive the individual action, changes or malfunctions of the components or was a whole. (Peterson et al. 1999; Meadows 2008).

The literature reviewed for this study is extensive; it ranged from theoretical papers to research papers, and articles. This review also draws upon research from both qualitative and quantitative research paradigms. More specifically, this literature review centers on research as it relates to historical background of inquiry, inquiry in STEM education and achieving 21st century skills through practicing inquiry. The overall goal of such an extensive approach was to provide a theoretical and conceptual framework for this study.

Conceptual Framework

Educational Theories of Science Education in Bangladesh

National science curriculum has recommended constructivist approach in Bangladesh (NCTB, 2012). It also recommended to the emphasis on constructivism in science education align with other learning theories: Thorndike trial and error theory, Pavlov's conditional reflexive theory, Gestalt theory, Piaget cognitive development theory. The curriculum also added constructivism in science education which should cover students previous knowledge, concept, and experiences; teachers should facilitate and create an opportunity to develop their laboratory experiments based on inquiry or a problem, build their experimental design, and classroom discourses. The curriculum also recommended that teachers should refine students experiences and knowledge based on their reflective practices. The teacher should also encourage students to work on groups (NCTB, 2012).

Siddique and Ikeda (2013) studied on secondary science teachers' beliefs about teaching and learning in Bangladesh. They found that there is no particular dimension of science teaching beliefs exist in their practice rather traditional transmission-based science teaching-learning which reflects the behavioral philosophy. The also mentioned that teachers' individual beliefs influence their science teaching practices.

Constructivism in Science Education

Although constructivism became part of science education, it has a long history to part of knowledge. However, Piaget considered as the father of constructivism of modern day. Constructivism theory, more specifically personal constructivism view of students, become part of education. Tobin and Topins (1993) defined constructivism in science education as process or construction of knowledge. They also added that experience is essential to construct scientific knowledge. At the same time, the discovered knowledge should be aligned with existing scientific discourses and community. As a result, it necessary for the students to discover knowledge they need essential scientific experiences based on their current knowledge. Tobin and Tobin also recommended that constructivism based curriculum design should cover students view, interests, previous experience, and knowledge. The redesigned curriculum should impact on teachers training and the pedagogy.

Research Problem in the framework

Tapan (2010) identified inquiry-based science teaching practice was the lack of teacher preparation, instructional resources, and the assessment system those was not able to synchronize with new inquiry-based science education. One the other hand, parents did not cooperate to implement the new inquiry-based science curriculum and textbook-based instruction were other important issues to incorporate inquiry-based teaching. Mojumdar, (2015) also identified that science teachers one-way transmission based science teaching is another challenge to incorporate inquiry-based science in Bangladesh. Therefore, it is imperative to assess teachers challenges and perceptions to implement inquiry-based science education in Bangladesh.

Bangladesh has been trying to align international contemporary science education concepts such as Inquiry, Scientific Literacy, Science for All, and STS for last forty years. STEM and three-dimensional learning have emerged as international contemporary science education movement. Based on this evolving science education movements, there is necessary reformation is necessary for current science education practice in Bangladesh.

NCTB has introduced science process skills in the science curriculum in Bangladesh (NCTB, 2012). Ostlund (1992) recommended some science process skills: observing, communicating, estimating, measuring, collecting data, classifying, inferring, predicting, making model, interpreting data, making graphs, hypothesizing, controlling variables, defining operationally, and investigating. On the other hand, Eisenkraft (2007) addressed five 21st century skills: adaptability, complex communication/social skills, nonroutine problem-solving skills, self-management/self-development skills, and system thinking (NRC, 2010). In" Pathways to Prosperity" report prepared by Harvard Graduate School of Education recommended for the more demanding labor market to the need for broader and deep skills and insights from a global perspective on education reform. In this circumstances, this study triangulated among three different concepts— inquiry, STEM education, and 21st-century skills under constructivism.

Figure 2.2:

Conceptual Framework for Science Education Reformation in Bangladesh

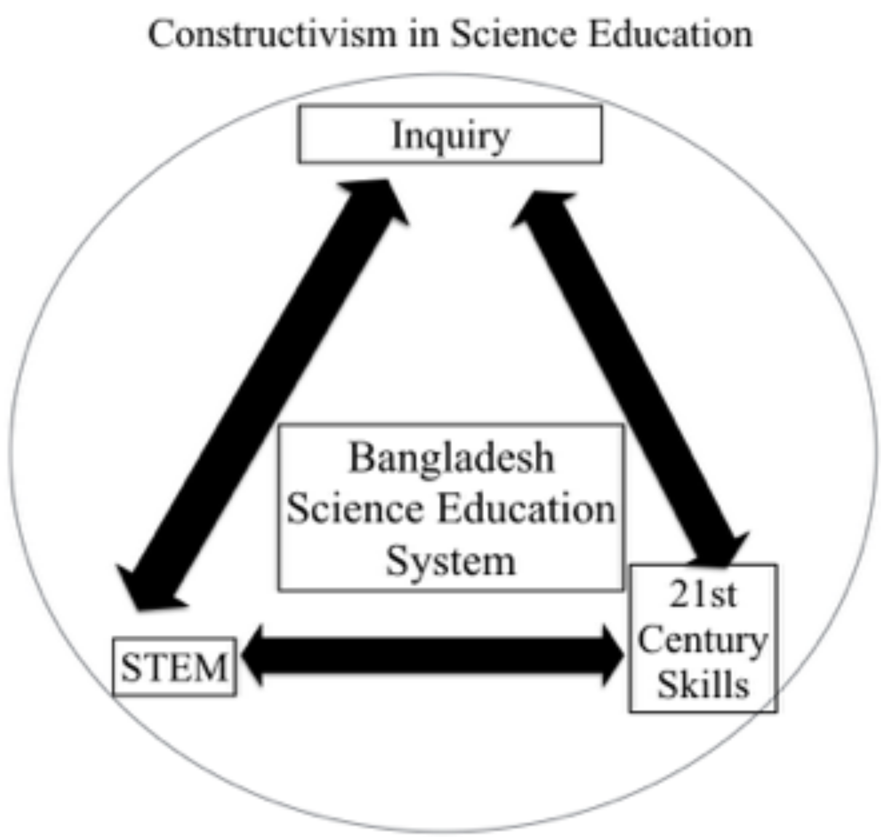


Figure Triangulation: Science education reformation triangulated under constructivism. Science education in Bangladesh needs blends inquiry, STEM, and 21st-century skills to make a successful transformation.

CHAPTER THREE

Methodology

This chapter will discuss about the method of the study. In this chapter there will be five different sections- (a) research design (b) subjects, sample, population (c) Instruments and Materials (d) Data Collection Procedure (variables/controls) and step by step process taken (e) Data Analysis.

Research Design

The research conducted in this study followed a quantitative survey methodology. Survey research design is a quantitative ways to describe certain populations' attitude, opinions, behaviors, or characteristics (Cresswell, 2013 & Cresswell, 2015). This study explored the current science education practices for middle level science teachers defined in Bangladesh as lower secondary level teachers working in grades 6-8 in Dhaka, Bangladesh. The focus of this research was the science teachers' current self-reported practices and attitudes towards teaching science within a traditional, British developed, educational system. Although the main focus of this research was science education practices in classrooms as reported by teachers, other essential school personnel was surveyed for their perceptions of practices and attitudes towards education in Bangladesh. The other essential personnel was include teacher training college instructors, and university faculties.

Survey research is an umbrella term. There is a variety of different forms of survey for gathering information under this term (Andres, 2012). Considering the survey format(s), there are two different perspectives and precepts covering two competing goals; mixed modes and mixed methods. The mixed modes approach utilizes more than one survey formats or mode to enhance the response rates (Andres, 2012). On the other hand, the mixed methods approach is to utilize more than one traditional survey method. Meaning that both quantitative and qualitative methods are used to overcome the survey method. Meaning that both qualitative and quantitative methods are used to overcome the survey barriers. Andres (2012) added that mixed methods survey research helps the researcher to utilize triangulation or sequential embedded design for more than one source of data to extend findings. Quantitative survey questions in this research used a Likert scale rating system. Qualitative survey questions were open ended question that allowed respondents to explain their thoughts on the questions more fully and accurately outside of the limitations of the Likert scale responses.

This research conducted in two different populations. The first population was include lower secondary level science teacher working in both public schools and private schools in Bangladesh. The second population was include professors and instructors at the teachers training college and university.

Sample, Population and Subjects

Participation in survey research typically required a random sampling of participants from the entire population. This study looked specifically at lower secondary school science teachers and administrators at the schools where they teach. Therefore, a purposeful selection procedure was used in this study to maximize the number of lower secondary school science teachers and administrators who were selected for this study. Babbie (1990) states that although a true random sample is desired, the there are instances where a "purposive or judgmental sample, wherein potential respondents are chosen on the basis of their convenience and availability (p.120) may be the best course of action for the outcomes of the research. Due to constraints of this research, including the ability to use electronic survey methods (all surveys were hand delivered), the challenges of geographic locations of participant schools, and the general conditions of third world country research including political and religious issues, purposeful selection methods must be the method used for this study of secondary school teacher and administrators.

The first population of participants was lower secondary level teachers (grade 6-8) located within the city of Dhaka, Bangladesh. Dhaka is by far the largest city within the country and serves as the capitol of Bangladesh with population of over 12.04 million people (BBS, 2011). In Dhaka, there are 556 secondary school with approximately 11, 223 teachers within those schools. Science teachers make up about 25% of that population or approximately 2,805 teachers. Using the sample size calculator (http://www.surveysystme.com/sscale.htm) with a 95% confidence level, and a +/-5 margin of error, a sample of 338 teachers were needed to be surveyed within the Dhaka lower secondary system.

Teachers Educators (Teacher Training College and University Faculties)

The second phase of data collection focused on the teacher educators, teachers training college instructors and university faculty. There are 118 teachers training colleges in Bangladesh, fourteen of them are run by government and 104 are private institutions. (Banbies, 2012). For the purpose of this research, only the government teacher training college faculty from across the country was surveyed. Around forty faculty members who are responsible for training teachers in science education was surveyed. There are only two public universities in Bangladesh where Education teaches as individual discipline. The University of Dhaka contains the Institute of Education and Research where teacher education takes place. There are five faculty members who are responsible for preparing science teachers. All five of these faculty members were surveyed.

Instrumentation:

This study followed survey research design. The survey will utilize a Likert scale for collecting the responses based on the research questions. All the participants from the school teachers were responded to the same items. One of the biggest challenge for the researcher was to translate the tools into Bengali since english is their second language.

Likert Type Scale:

The likert scale was developed based on the research questions, theoretical framework and literature review. The likert type scale was consist of three sections. The first section was on participants demographic information related to their academic and professional information.

The second section of the likert scale was on science teachers instructional beliefs and practices. This section mainly focused on what are the current science teaching methods they were following. The items were selected based on what were current practices they were doing right now and what kind of challenges they were encountering and what kinds of changes they were expecting. The basic purpose of this section was to understand the instructional beliefs and practices among the teachers, administrators and educators. The study used liker scale with 6 categories of response (1= very strongly disagree (VSA), 2= strongly disagree(SA), 3= agree(A), 4= agree(D), 5= strongly agree(DA), 6= very strongly agree (VSD).

The third section of the survey was focused on STEM-related practices. This section was on the degree of self-reported integration of multiple subjects in science classroom, instructional equipment, and teachers' preparation. The items were selected based on current science education practices and their tentative integration. At the same time, the questioned were focused on implicating the changes the expect in science education. Additionally, what participants responded on inaugurating such kind of addendum in the curriculum and teacher program.

The final section consisted on open ended questions. Questionnaires were effective data collection tools for large population with a limited amount of time. This questionnaire looked for additional information from the participants. It provided opportunity for the participants to express their own views on instructional practices and science education. It consisted of six open-ended questions three different group of participants- school science teachers, teacher educators and administrators.

Data Collection Procedure:

The research collected data from secondary schools in Dhaka City. The schools were be selected randomly from the capital. Dhaka University was considered as the central point for selecting schools. All the schools were selected within 10 miles from the central point. The science teachers were selected from each school; each teacher were identified with a a ID number. Out of four hundred participants, 360 science teachers filled out the form and researcher collected the form. Another group of forty participants were science educators from Dhaka University and Dhaka Teachers Training College. The number of participant faculty in Dhaka University is around 5 and Teachers Training College faculty members around 35. The researcher communicated for a tentative schedule and meet them with the survey tools. The researcher took permission from ministry of education, government of Bangladesh to collect data from the educational institutions, specially from the secondary schools.

Data Analysis

The survey consisted of several components: (1) Teacher background information (i.e. name, year graduated the master's program), and school information (i.e. grade level, subjects taught, materials for to conduct inquiry and/or problem solving), (2) liker scale inquiry based and STEM questions (3) open-ended qualitative responses.

Likert Scale Data:

The study used central tendency statistics to analyze the data. Since the mean (and standard deviation) are inappropriate for ordinal data, the study will use median or mode as the 'measure central tendency' for it's ordinal data.

Questionnaire Data:

The remaining survey items were used to gather additional information on teachers' inquiry and STEM related practices and were provide a crosscheck for closed-ended survey items. The open ended data were analyzed using a hybrid approach to thematic analysis (Fereday & Muir-Cochrane, 2008) to find out the teachers beliefs and practices on classroom instruction and science education. The thematic approach was qualitative data analysis process based on inductive and deductive approach.

CHAPTER FOUR

Results

Survey- Part A

Demographics

This section of the chapter will describe in the demographics of the study. The study has focused on participants professional role, teaching curriculum or medium of instruction, gender, age of the participants, professional position, professional duration, obtained degrees, and teaching subjects.

Table 4.1 presents the percentage of the participants in professional role. The table demonstrates that 1.24% head teachers, 78.05% science teacher, 20.69% others such as computer science teachers.

Table 4.1

Presents the percentage of the participants in professional role.

Teacher Professional Role	No. of Participants (N=400)	Percentages (%)
Head Teacher	5	1.24
Science Teacher	312	78.05
Others	83	20.69

Figure 4.1 Presents the percentage of the participants in professional role.

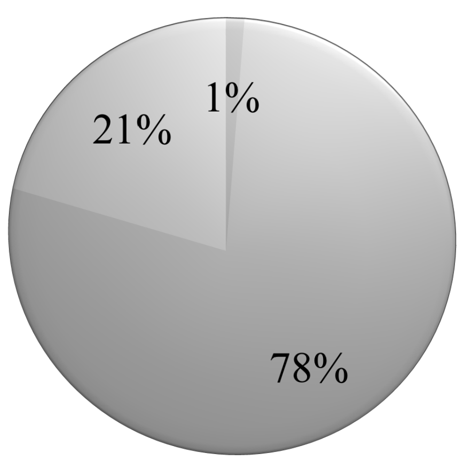


Table 4.2 presents the percentage of medium of instruction of the participants used to teach. The table shows that 85.25% Bengali version science curriculum and 14.75% English version science curriculum.

Table 4.2

Percentage of medium of instruction of the participants

Curriculum/ Medium of Instruction	No of Participants (N=400)	Percentages (%)
Bengali	341	85.25
English	59	14.75

Figure 4.2 Percentage of medium of instruction of the participants.

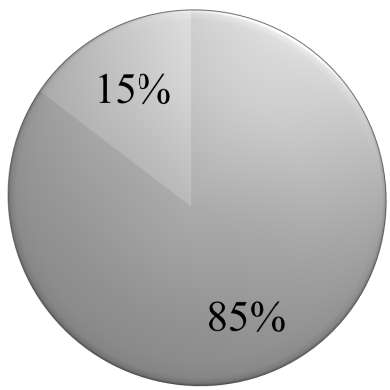


Table 4.3 presents the percentage of the participants gender. The table shows that 68% participants were male and 31.25% were female, and 0.75% didn't responded the statement.

Table 4.3

Percentage of the participants gender.

Gender	No. of Participants (N=400)	Percentages (%)
Female	125	31.25
Male	272	68
No Response	3	0.75

Figure 4.3 Percentage of the participants gender.

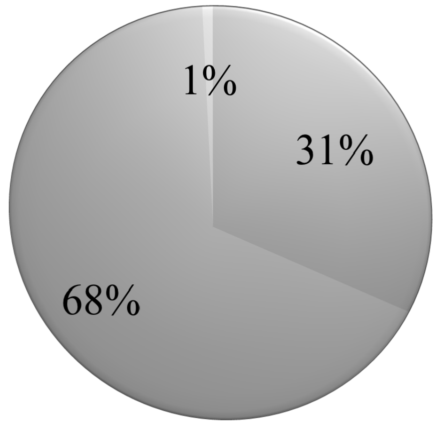


Table 4.4 presents the percentage of the participants' age. The table shows that 11% participants were 24-29 years, 24.25% were 30-34 years old, 18.25% were 35-39 years old, 15.5% participants were 40–44 years old, 15.75% participants were 45-49 years old, 50+ years old participants were 14.25%, and 1.0% didn't responded the statement.

Table 4.4

Presents the percentage of the participants' age.

Year	No. of Participants (N=400)	Percentages (%)
24-29	44	11.0
30-34	97	24.25
35-39	73	18.25
40-44	62	15.5
45-49	63	15.75
50+-	57	14.25
No Response	4	1.0

Figure 4.4 Presents the percentage of the participants' age.

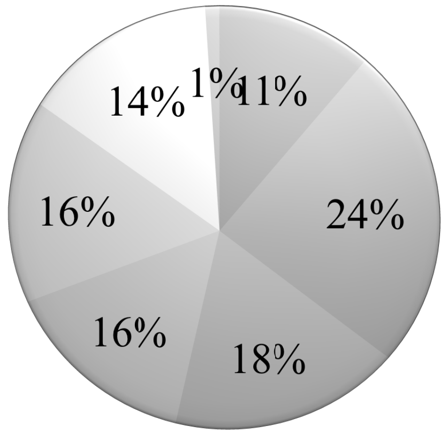


Table 4.5 presents the percentage of the participants teaching experience. The table shows that 33.75% participants have 0-5 years professional experience, 19.25% have 6-10 years, 14.75% have 11-15 years, 12.5% have 16-20 years, 17.0% have more than 21 years, and 2.75% didn't respond to the statement.

Table 4.5

Percentage of the participants teaching experience.

Years	No. of Participants (N=400)	Percentages (%)
0-5	135	33.75
6-10	77	19.25
11-15	59	14.75
16-20	50	12.5
21+	68	17.0
No Response	11	2.75

Figure 4.5 Percentage of the participants teaching experience.

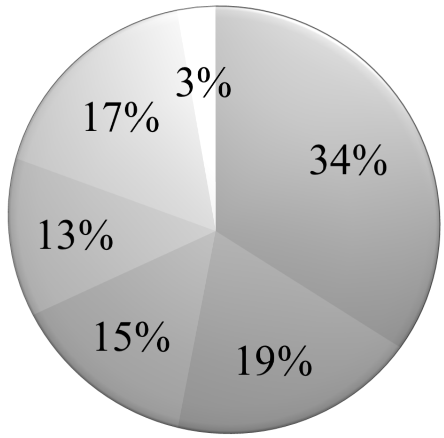


Table 4.6 presents the frequency and percentage of the participants teaching position. The table shows that 36.25% were Assistant teachers, 4.5% Junior teachers, 38.50% Senior teachers, 8.0 Assistant Head teachers, 3.0% Head teachers, 7.50% faculty members from teacher training college and universities, and 2.25% of the participants missed the statement.

Table 4.6:

Percentage of the participants teaching position.

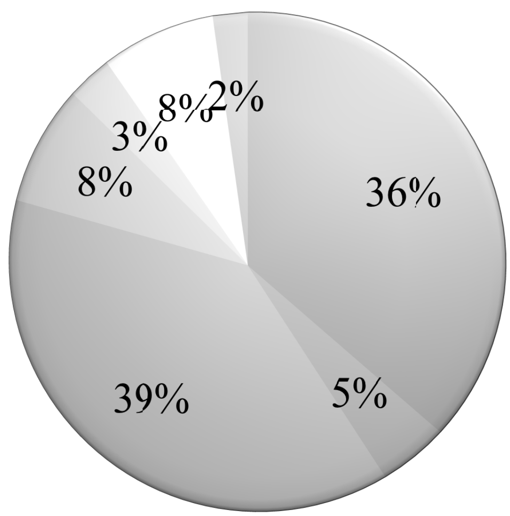
Teacher Professional Position	No. of Participants (N=400)	Percentages (%)
Assistant Teacher	145	36.25
Junior Teacher	18	4.5
Senior Teacher	154	38.50
Assistant Head Teacher	32	8.0
Head Teacher	12	3.0
Faculty	30	7.50
No Response	9	2.25

Figure: 4.6 Percentage of the participants teaching position

Table 4.7 presents the percentage of the participants in professional degree. The table shows that 1.00 % participants have a Ph.D. degree, 2.0 % participants have M.Phil, 71.0 % participants have a masters degree, 13.0 % participants have a bachelor degree, 12.0 % have 3 years bachelor degree, and 1.0 % didn't respond to the statement.

Table 4.7

Percentage of the participants in professional degree.



Highest Degree	No. of Participants (N=400)	Percentages (%)
Ph.D.	4	1.00
M.Phil	8	2.00
Masters	284	71.00
Bachelor (4 years)	52	13.00
Bachelor Degree (3 years/ Pass)	48	12.00
No Response	4	1.00

Figure 4.7 Percentage of the participants in professional degree.

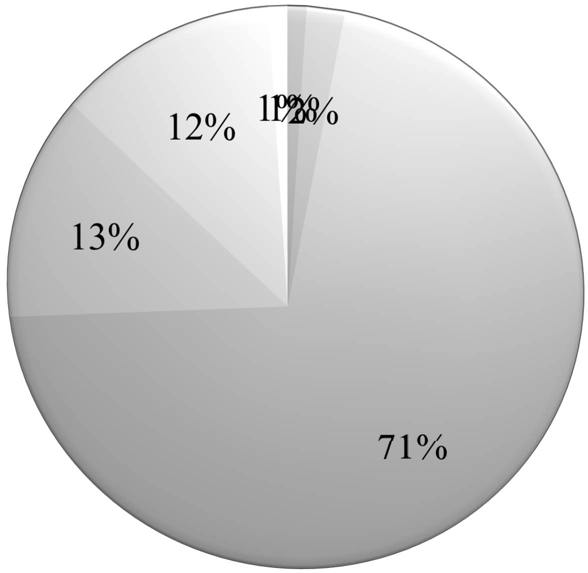


Table 4.8 presents the percentage of the participants' undergraduate degree. The table shows that 59.0 % participants have bachelor of science degree, 2.0 % have bachelor social science degree, 3.5 % have bachelor of arts degree, 7.0 % have bachelor of education degree, and 26.5 % have others degree such as computer science teachers, and 2.0 % have missed the statement.

Table 4.8

Percentage of undergraduate degree of the participants.

Bachelor	No. of Participants (N=400)	Percentages (%)
Bachelor of Science	236	59.00
Bachelor of Social Science (BSS)	8	2.00
Bachelor of Arts	14	3.50
Bachelor of Education (B.Ed)	28	7.00

Others	106	26.50
No Response	8	2.00

Figure: 4.8 Percentage of undergraduate degree of the participants

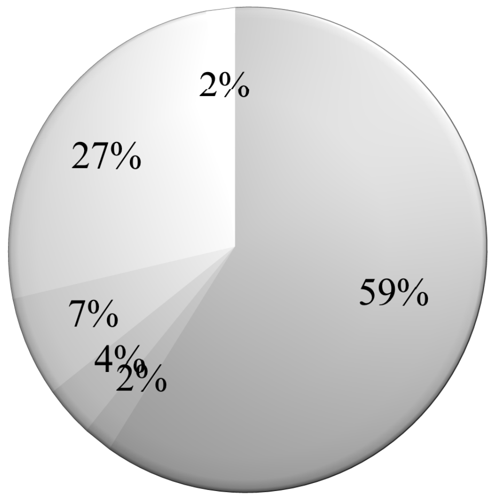


Table 4.9 presents the percentage of the undergraduate degree of the participants. The table shows that 6.25% participants have biology degree, 17.25% have degree in chemistry, 17.50% have degree in physics, 10.25% degree in Zoology, 5.0 have degree in Science Education and 41.5% have others degree such as computer science teachers, and 2.25% missed the statement.

Table 4.9

Participants major undergraduate degree.

Undergraduate Major	No. of Participants (N=400)	Percentages (%)
Botany	25	6.25
Chemistry	69	17.25
Physics	70	17.50
Zoology	41	10.25

B.Ed (Science Education)	20	5.0
Others	166	41.5
No Response	9	2.25

Figure: 4.9 Participants major undergraduate degree.

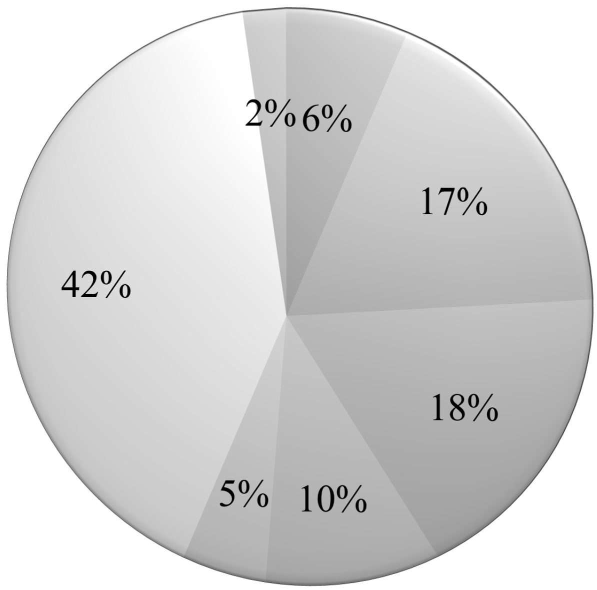


Table 4.10 presents the percentage of the participants masters degree. The table shows that 74.75% participants have a master's degree and 23.0% don’t have a masters degree. 1.25% participants didn’t respond to the statement.

Table: 4.10

Percentage of participants masters degree

Masters Degree	No. of Participants (N=400)	Percentages (%)
Have a master’s degree	299	74.75
Haven’t a master’s degree	92	23.0
No Response	9	1.25

Figure: 10 Percentage of participants masters degree.

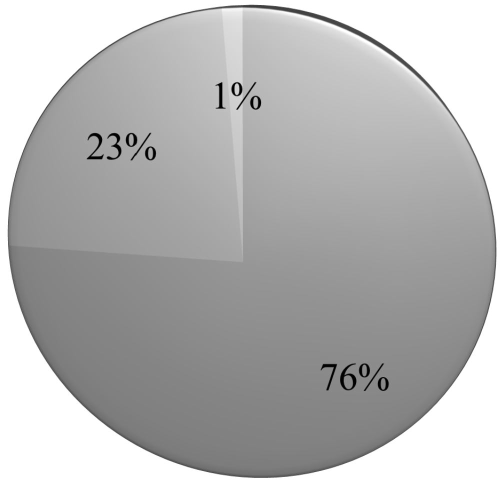


Table 4.11 presents the percentage of the participants' major areas of masters degree.The table shows that 14.25% participants have masters in botany, 12.0 % have degree in chemistry, 11.0% have degree in physics, 18.0 % degree in Zoology, 10.25% have masters in Science Education, 20.0% have others masters degree such as computer science teachers, 28% don't have any master degree, and 1.50% missed the statement.

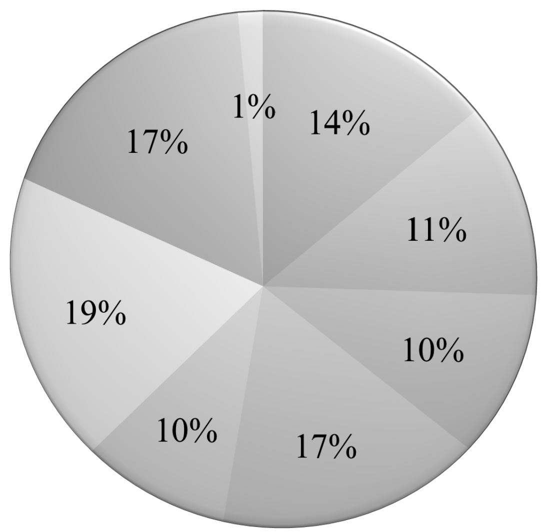
Table 4.11

Percentage of the participants' major areas of masters degree.

Graduate Major Areas	No of Participants (N=400)	Percentages (%)
Botany	57	14.25
Chemistry	48	12.0
Physics	44	11.0
Zoology	52	18.0
M.Ed (Science Education)	41	10.25
Others	80	20.0
Not Acceptable	72	18.0

No Response	6	1.50

Figure 4.11 Percentage of the participants' major areas of masters degree.



Survey – Part B

Science Teachers Instructional Beliefs and Practices

The following tables display the frequency results for Part A of the survey. Table 4.12 presents the frequencies for Statement 1, "I understand what is meant by "inquiry teaching". Responses from all participants are almost evenly distributed among 'agree', 'strongly agree', and 'very strongly agree'. The average response score was 5.14 which confirms that the teachers understand inquiry based science teaching.

Table 4.12

Frequency Table for Statement 1

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	2	0.5
Strongly Disagree (2)	2	0.5
Disagree (3)	2	0.5
Agree (4)	82	20.5
Strongly Agree (5)	134	33.4
Very Strongly Agree (6)	174	43.5
No Response	4	1.0
Average Response Score	5.14/ 6.00	

Table 4.13 presents the frequencies and percentages for statement 2 "I often use inquiry in my teaching". The majority of participants agree with the statement with 93% choosing either 'agree', 'strongly agree' or 'very strongly agree'. The teachers had a

slightly greater average response score 5.07 which reflect that teachers use of inquiry in their science classroom.

Table 4.13

Frequency Table for Statement 2

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	5	1.3
Strongly Disagree (2)	2	1.3
Disagree (3)	15	3.8
Agree (4)	64	16.0
Strongly Agree (5)	137	34.3
Very Strongly Agree (6)	172	43.0
No Response	5	1.3
Average Response Score	5.07 / 6.00	

Table 4.14 presents the frequencies and percentages for statement 3 “I provide hands-on activities to help students understand scientific concepts”. Most of the participants selected either ‘agree’, ’strongly agree’ or ‘very strongly agree’. The mean score for the statement was 5.07, providing evidence that suggests the teachers incorporate hands-on activities to help students to understand scientific concepts.

Table 4.14

Frequency Table for Statement 3

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	1	0.3

Strongly Disagree (2)	2	0.5
Disagree (3)	10	2.5
Agree (4)	59	14.8
Strongly Agree (5)	150	37.5
Very Strongly Agree (6)	176	44.0
No Response	2	0.5
Average Response Score	5.19 / 6.00	

Table 4.15 presents the frequencies and percentages for statement 4 “I encourage the students to experience natural phenomena such as gravity, light, and magnetism”. The results show over 95% the participants choosing ‘agree’ and above, and half of them very strongly agree. The average response was a 5.27, confirms participants’ choices about the statement which is above of ‘strongly agree’.

Table 4.15

Frequency Table for Statement 4

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	0	0.0
Strongly Disagree (2)	2	0.5
Disagree (3)	10	2.5
Agree (4)	53	13.3
Strongly Agree (5)	132	33.0
Very Strongly Agree (6)	200	50.0
No Response	3	0.8
Average Response Score	5.27 / 6.00	

Table 4.16 presents the frequencies and percentages for statement 5 "I begin my lesson with probing questions focused on the lesson concept". The majority of participants, 54% 'very strongly agree', 32.5% 'strongly agree' and 11.5% 'agree' with an average response score of 5.36. The average response score for the statement indicates that the teachers are used to teaching a science lesson with probing questions. Beside this, more than half of the teachers 'very strongly agree' with the statement.

Table 4.16

Frequency Table for Statement 5

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	1	0.3
Strongly Disagree (2)	1	0.3
Disagree (3)	4	1.0
Agree (4)	46	11.5
Strongly Agree (5)	130	32.5
Very Strongly Agree (6)	216	54.0
No Response	2	0.5
Average Response Score	5.36 / 6.00	

Table 4.17 presents the frequencies and percentages for statement 6 " I give the opportunity to students to set up their own activities for exploring natural phenomena". Most of the participants responded 'agree' or above with the statement. Among them, more than one-third of the participants 'strongly agree' and 'very strongly agree'. The average response score was 4.99, just below the 'strongly agree' option.

Table 4.17

Frequency Table for Statement 6

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	2	0.5
Strongly Disagree (2)	6	1.5
Disagree (3)	14	3.5
Agree (4)	72	18.0
Strongly Agree (5)	154	38.5
Very Strongly Agree (6)	147	36.8
No Response	5	1.3
Average Response Score	4.99 / 6.00	

Table 4.18 presents the frequencies and percentages for statement 7 “I use technology such as computers, PowerPoint software, tablets, the internet, or videos to enhance student learning”. The participants’ responses were more spread out with the statement, although almost 85% of the teachers ‘agree’ and above with the statement. One-third or above ‘very strongly agree’ with the statement. In other words, teachers are used to with internet and electronic devices in their classrooms and lessons.

Table 4.18

Frequency Table for Statement 7

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	18	4.5
Strongly Disagree (2)	12	3.0

Disagree (3)	31	7.8
Agree (4)	79	19.8
Strongly Agree (5)	115	28.7
Very Strongly Agree (6)	141	35.3
No Response	4	1.0
Average Response Score	4.68 / 6.00	

Table 4.19 presents the frequencies and percentages for statement 8 "I often use teacher investigations all year long". More than 99% participants chose 'agree' or above and within this 40% teachers 'strongly agree' with the statement, 28% 'very strongly agree'. The average response among the participants is 4.83, which is below than 'strongly agree'. In other words, teachers are highly engage in investigation method to teach science in their classrooms.

Table 4.19

Frequency Table for Statement 8

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	1	0.3
Strongly Disagree (2)	8	0.3
Disagree (3)	26	6.5
Agree (4)	87	21.8
Strongly Agree (5)	163	40.8
Very Strongly Agree (6)	112	28.0
No Response	3	0.8
Average Response Score	4.83 / 6.00	

Table 4.20 presents the frequencies and percentages for statement 9 “I often use teacher demonstrations all year long”. More than 90% of the participants selected ‘agree’, ‘strongly agree’ or ‘very strongly agree’. The average response score , 4.92, supports the participants’ ‘strongly agree’ choice. This means that teachers are used to deliver their science lesson through demonstrating scientific concepts.

Table 4.20

Frequency Table for Statement 9

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage
Very Strongly Disagree (1)	0	0
Strongly Disagree (2)	6	1.5
Disagree (3)	14	3.5
Agree (4)	84	21.0
Strongly Agree (5)	163	40.8
Very Strongly Agree (6)	127	31.8
No Response	6	1.5
Average Response Score	4.92 / 6.00	

Table 4.21 presents the frequencies and percentages for statement 10 “I often use lecture all year long”. More than 75% of the teachers responded that they use lecture method all year long as a science teaching method. The average response, 4.16, also reflect their opinion.

Table 4.21

Frequency Table for Statement 10

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	17	4.3
Strongly Disagree (2)	26	6.5
Disagree (3)	52	13.0
Agree (4)	127	31.8
Strongly Agree (5)	72	18.0
Very Strongly Agree (6)	95	23.8
No Response	11	2.8
Average Response Score	4.16 / 6.00	

Table 4.22 presents the frequencies and percentages for statement 11 “I often have students collect data from investigations or demonstrations”. Almost 90% of the participants chose either ‘agree’, ‘strongly agree’, or ‘very strongly agree’. The mean response score was 4.6, which reflects that teacher agreed with the statement.

Table 4.22

Frequency Table for Statement 11

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	3	0.8
Strongly Disagree (2)	10	2.5
Disagree (3)	31	7.8
Agree (4)	124	31.0

Strongly Agree (5)	128	32.0
Very Strongly Agree (6)	98	24.5
No Response	6	1.5
Average Response Score	4.6 / 6.00	

Table 4.23 presents the frequencies and percentages for statement 12 “I often have students collect data from demonstrations”. More than 90% of the teacher responded that they ask students to apply scientific concepts in new context. The average response score was 4.6 or above ‘agree’.

Table 4.23

Frequency Table for Statement 12

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	4	1.0
Strongly Disagree (2)	9	2.3
Disagree (3)	31	7.8
Agree (4)	125	31.3
Strongly Agree (5)	142	35.5
Very Strongly Agree (6)	86	21.5
No Response	3	0.8
Average Response Score	4.6 / 6.00	

Table 4.24 presents the frequency and percentage of the participants’ for statement 13 “I often use textbook for most of my science teaching.”. Participants responses were split into half; half of the teachers ‘agree’ or above, and the rest of them ‘disagree’ and

below. However, the average response score was just below ‘agree’. It reflects that the teachers have not mastered enough to use the textbook more than as content or reference.

Table 4.24

Frequency Table for Statement 13

Answer Choices	Frequencies and Percentages	
	Teacher	Percentages (%)
Very Strongly Disagree (1)	62	15.5
Strongly Disagree (2)	40	10.0
Disagree (3)	77	19.3
Agree (4)	101	25.3
Strongly Agree (5)	57	14.2
Very Strongly Agree (6)	59	14.8
No Response	4	1.0
Average Response Score	3.54 / 6.00	

Table 4.25 presents the frequencies and percentages for statement 14 “I often ask students to apply what they have learned in a new context (science/ engineering problem)”. More than 90% of the ask students to apply scientific concepts in a new context. The average is 4.95 or just below ‘strongly agree’.

Table 4.25

Frequency Table for Statement 14

Answer Choices	Frequencies and Percentages	
	Teacher	Percentages (%)
Very Strongly Disagree (1)	2	0.5

Strongly Disagree (2)	7	1.8
Disagree (3)	21	5.3
Agree (4)	80	20.0
Strongly Agree (5)	136	34.0
Very Strongly Agree (6)	150	37.5
No Response	4	1.0
Average Response Score	4.95 / 6.00	

Table 4.26 presents the frequencies and percentages for statement 15 “I often encourage students to use multi-modal presentation tools such as graphs or tables to present their results”. Almost two-third of the participants either ‘strongly agree’ or ‘very strongly agree’. The average response was 4.77. In other words, the teachers encourage students to use multi-model presentation tools to present scientific concepts.

Table 4.26

Frequency Table for Statement 15

Answer Choices	Frequencies and Percentages	
	Teacher	Percentages (%)
Very Strongly Disagree (1)	2	0.5
Strongly Disagree (2)	9	2.3
Disagree (3)	27	6.8
Agree (4)	105	26.3
Strongly Agree (5)	132	33.0
Very Strongly Agree (6)	121	30.0
No Response	4	1.0
Average Response Score	4.77 / 6.00	

Table 4.27 presents the frequencies and percentages for statement 16 “I often encourage students to do internet-based research about the phenomena under study”. 94% teacher responded that they use internet-based research to teach science in their classrooms. The average response is 5.00.

Table 4.27

Frequency Table for Statement 16

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	4	1.0
Strongly Disagree (2)	6	1.5
Disagree (3)	11	2.8
Agree (4)	90	22.5
Strongly Agree (5)	126	31.5
Very Strongly Agree (6)	160	40.0
No Response	3	0.8
Average Response Score	5 / 6.00	

Table 4.28 represents the frequencies and percentages for statement 17 “I often assess students’ science process skills such as steps in the activities or problem solving”. More than 80% of the participants responded with the statement. Above them, more than one-third of them ‘very strongly agree’ with the statement. The average response is 4.66.

Table 4.28

Frequency Table for Statement 17

Answer Choices	Frequencies and Percentages

	Teacher	Percentage (%)
Very Strongly Disagree (1)	14	3.5
Strongly Disagree (2)	8	2.0
Disagree (3)	31	7.8
Agree (4)	98	24.5
Strongly Agree (5)	116	29.0
Very Strongly Agree (6)	128	32.0
No Response	5	1.3
Average Response Score	4.66 / 6.00	

Table 4.29 displays the frequencies and percentages for statement 18 "I have been trained in inquiry as part of my in-service training". The response among the teachers were little bit scattered. Although more than half of the teaches agree or above that they have in-service inquiry training for teaching science, the rest of them disagree or below that they never received in-service inquiry training for teaching science. Supporting the result, the average responses in 3.79, which is between 'agree' and 'disagree'.

Table 4.29

Frequency Table for Statement 18

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	78	19.5
Strongly Disagree (2)	14	3.5
Disagree (3)	48	12.0
Agree (4)	95	23.8
Strongly Agree (5)	73	18.3

Very Strongly Agree (6)	87	21.8
No Response	5	1,3
Average Response Score	3.79 / 6.00	

Table 4.30 presents the frequencies and percentages for statement 19 “I think in-service training would help me implement inquiry in the classrooms”. More than one-fifth of the teacher responded that they don’t have enough training to implement inquiry in their classroom, rest of them responded opposite. The average response score was 4.32.

Table 4.30

Frequency Table for Statement 19

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	42	10.5
Strongly Disagree (2)	12	3.0
Disagree (3)	35	8.8
Agree (4)	103	25.8
Strongly Agree (5)	73	18.3
Very Strongly Agree (6)	130	25.8
No Response	5	1.3
Average Response Score	4.32 / 6.00	

Table 4.31 presents the frequencies and percentages for statement 20 “I think my present curriculum is good enough to help me to use inquiry in my teaching”. The responses among the the teachers were scattered. Although two-thirds of the teachers responded that the present science curriculum is good enough to incorporate inquiry in

science classrooms; one-third of the teachers don't comply with it. Following those, the average response was 3.99, just below 'agree'.

Table 4.31

Frequency Table for Statement 20

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	56	14.0
Strongly Disagree (2)	33	8.3
Disagree (3)	46	11.5
Agree (4)	86	21.5
Strongly Agree (5)	71	17.8
Very Strongly Agree (6)	106	26.5
No Response	2	0.5
Average Response Score	3.99 / 6.00	

Table 4.32 presents the frequencies and percentages for statement 21 "I think schools have enough equipment and required facilities to practice inquiry in teaching". The responses almost split half and half between 'agree' and above, and 'disagree' and below. The average response, 3.37, reflects the split with the statement. In other words, teachers do not satisfy with their science teaching resources to introduce inquiry.

Table 4.32

Frequency Table for Statement 21

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	95	23.8

Strongly Disagree (2)	57	14.2
Disagree (3)	47	11.8
Agree (4)	63	15.8
Strongly Agree (5)	69	17.3
Very Strongly Agree (6)	67	16.8
No Response	2	0.5
Average Response Score	3.37 / 6.00	

Table 4.33 presents the frequencies and percentages for statement 22 “Administrators can help teachers begin to practice new science methods such as inquiry in classrooms”. More than 90% of the participants responded that administrators could have enough influence to implement new science teaching method such a inquiry. The average response is 5.0, which reflects the response.

Table 4.33

Frequency Table for Statement 22

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	7	1.8
Strongly Disagree (2)	5	1.3
Disagree (3)	18	4.5
Agree (4)	77	19.3
Strongly Agree (5)	117	29.3
Very Strongly Agree (6)	173	43.3
No Response	3	0.8
Average Response Score	5.01 / 6.00	

Table 4.34 presents the frequencies and percentages for statement 23 “I know about the learning cycle as a way of teaching inquiry science”. The participants responded that they have wide knowledge on learning cycle to teach inquiry in science classrooms. More than one-third of the participants responded ‘agree’ and others above than ‘agree’ with the statement. The average response, 4.41, reflects the teachers responses.

Table 4.34

Frequency Table for Statement 23

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	12	3.0
Strongly Disagree (2)	11	2.8
Disagree (3)	37	9.3
Agree (4)	149	37.3
Strongly Agree (5)	101	25.3
Very Strongly Agree (6)	86	21.5
No Response	4	1.0
Average Response Score	4.41 / 6.00	

Table 4.35 presents the frequencies and percentages for statement 24 “I think that memorization is the most important in learning science/ STEM”. The participants responded that memorization is not a good strategy to learn science. More than half of the participants responded ‘very strongly disagree’ which imply that memorization is not good for learning science. The average was 1.95 which exactly reflect the response.

Table 4.35

Frequency Table for Statement 24

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	219	54.8
Strongly Disagree (2)	67	16.8
Disagree (3)	57	14.2
Agree (4)	22	5.5
Strongly Agree (5)	18	4.5
Very Strongly Agree (6)	13	3.3
No Response	4	1.0
Average Response Score	1.95 / 6.00	

Table 4.36 presents the frequencies and percentages for statement 25 “I think teacher is generally responsible for students’ learning in science”. The responses were quite scattered. However, more than half of the participants ‘agree’ and above and the rest half ‘disagree’ and below. The average response was 3.44.

Table 4.36

Frequency Table for Statement 25

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	73	18.3
Strongly Disagree (2)	39	9.8
Disagree (3)	67	16.8
Agree (4)	100	25.0

Strongly Agree (5)	71	17.0
Very Strongly Agree (6)	45	11.3
No Response	5	1,3
Average Response Score	3.44 / 6.00	

Table 4.37 presents the frequencies and percentages for statement 26 "I think students' learning in science is directly related to their teacher's effectiveness in science teaching". One-third of the participants responded 'disagree' or below, and rest of the participants 'agree' or above with the statement. The average response score 4.00 was also imply the result.

Table 4.37

Frequency Table for Statement 26

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	35	8.8
Strongly Disagree (2)	33	8.3
Disagree (3)	67	16.8
Agree (4)	97	24.3
Strongly Agree (5)	68	17.0
Very Strongly Agree (6)	95	23.8
No Response	5	1.3
Average Response Score	4 / 6.00	

Table 4.38 presents the frequencies and percentages for statement 27 "I often encourage students more group work than individual". Most of the teachers responded

'agree' or above with the statement. It implies that students are being encouraged to work in groups rather than individual.

Table 4.38

Frequency Table for Statement 27

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	3	0.8
Strongly Disagree (2)	16	4.0
Disagree (3)	18	4.5
Agree (4)	112	28.0
Strongly Agree (5)	107	26.8
Very Strongly Agree (6)	140	35.0
No Response	4	1.0
Average Response Score	4.78 / 6.00	

Table 4.39 Survey Summary (Part B)

Science Teachers Instructional Beliefs and Practices

No.	Items	Mean	Median	Mode	Standard Deviation (S.D.)
1	I understand what is meant by "inquiry teaching".	5.14	5.00	6	1.01
2	I often use inquiry in my teaching.	5.07	5.07	6	1.13
3	I provide hands-on activities to help students understand scientific concepts.	5.19	5.00	6	0.929

4	I encourage the students to experience natural phenomena such as gravity, light, and magnetism.	5.27	5.50	6	0.947
5	I begin my lesson with probing questions focused on the lesson concept.	5.36	6.00	6	0.868
6	I give the opportunity to students to set up their own activities for exploring natural phenomena.	4.99	5.00	5	1.10
7	I use technology such as computers, PowerPoint software, tablets, the internet, or videos to enhance student learning.	4.68	5.00	6	1.41
8	I often use teacher investigations all year long.	4.83	5.00	5	1.06
9	I often use teacher demonstrations all year long.	4.92	5.00	5	1.08
10	I often use lecture all year long.	4.16	4.00	4	1.52
11	I often have students collect data from investigations or demonstrations.	4.60	5.00	5	1.19
12	I often have students collect data from demonstrations.	4.60	5.00	5	1.11
13	I often use textbook for most of my science teaching.	3.54	4.00	4	1.63
14	I often ask students to apply what they have learned in a new context (science/ engineering problem)	4.95	5.00	6	1.12
15	I often encourage students to use multi-modal presentation tools such as graphs or tables to present their results	4.77	5.00	5	1.14
16	I often encourage students to do internet-based research about the phenomena under study	5.00	5.00	6	1.10

17	I often assess students' science process skills such as steps in the activities or problem solving.	4.66	5.00	6	1.34
18	I have been trained in inquiry as part of my in-service training.	3.79	4.00	4	1.79
19	I think in-service training would help me implement inquiry in the classrooms.	4.32	5.00	6	1.65
20	I think my present curriculum is good enough to help me to use inquiry in my teaching.	3.99	4.00	6	1.74
21	I think schools have enough equipment and required facilities to practice inquiry in teaching.	3.37	3.00	1	1.83
22	Administrators can help teachers begin to practice new science methods such as inquiry in classrooms.	5.01	5.00	6	1.17
23	I know about the learning cycle as a way of teaching inquiry science.	4.41	4.00	4	1.25
24	I think that memorization is the most important in learning science/ STEM.	1.95	1.00	1	1.37
25	I think teacher is generally responsible for students' learning in science.	3.44	4.00	4	1.65
26	I think students' learning in science is directly related to their teacher's effectiveness in science teaching.	4.00	4.00	4	1.61
27	I often encourage students more group work than individual.	4.78	5.00	6	1.22

Survey – Part C

Science, Technology, Engineering, and Mathematics Education

The following tables display the frequency results for Part A of the survey. Table 4.40 presents the frequencies for Statement 1, "I understand what is meant by "STEM". Responses from the teachers were little bit scattered; more than one-third of the participants 'disagree' or beyond with the statement and rest of them know about the meaning of 'STEM'. The average response score was 3.97, which is just below 'agree'.

Table 4.40

Frequency Table for Statement 1

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	64	16.0
Strongly Disagree (2)	11	2.8
Disagree (3)	46	11.5
Agree (4)	92	23.0
Strongly Agree (5)	84	21.0
Very Strongly Agree (6)	96	24.0
No Response	7	1.8
Average Response Score	3.97 / 6.00	

Table 4.41 presents the frequencies and percentages for statement 2 "I try to integrate engineering with science in lessons.". The majority of participants agree with the statement with 10.3% chose 'agree', 31.3% 'strongly agree', and 18.8% 'very strongly agree'. The teachers had a slightly greater average response score than 'agree'.

Table 4.41

Frequency Table for Statement 2

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	25	6.3
Strongly Disagree (2)	7	1.8
Disagree (3)	43	10.8
Agree (4)	121	10.3
Strongly Agree (5)	125	31.3
Very Strongly Agree (6)	75	18.8
No Response	4	1.0
Average Response Score	4.32 / 6.00	

Table 4.42 presents the frequencies and percentages for statement 3 “I try to integrate mathematics with science in lessons.”. 30% of the participants ‘agree’, other 30% ‘strongly agree’ and rest 30% ‘very strongly agree’. The mean score for statement 3 was 4.56, providing evidence that suggests the participants integrate mathematics with science in lessons.

Table 4.42

Frequency Table for Statement 3

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	18	4.5
Strongly Disagree (2)	7	1.5
Disagree (3)	30	7.5

Agree (4)	118	29.5
Strongly Agree (5)	108	27.0
Very Strongly Agree (6)	115	28.7
No Response	4	1.0
Average Response Score	4.56 / 6.00	

Table 4.43 presents the frequencies and percentages for statement 4 “I try to integrate technology with science in lessons.”. The results show that more than 85% participants ‘agree’ or above with the statement. In other words, the participants are used to integrate technology with their science lessons. The average response score was 4.64.

Table 4.43

Frequency Table for Statement 4

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	18	4.5
Strongly Disagree (2)	6	1.5
Disagree (3)	32	8.0
Agree (4)	96	24.0
Strongly Agree (5)	111	27.8
Very Strongly Agree (6)	132	33.0
No Response	5	1.3
Average Response Score	4.64 / 6.00	

Table 4.44 presents the frequencies and percentages for statement 5 “I try to teach science and integrate at least two other of the following disciplines- engineering, technology or mathematics.”. The majority of participants 25.% chose ‘agree’, 27.3%

'strongly agree', and 25.5% 'very strongly agree' with an average response of 4.35 which support the choice and suggest participants integrate at least two other discipline with science.

Table 4.44

Frequency Table for Statement 5

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	31	7.8
Strongly Disagree (2)	10	2.5
Disagree (3)	42	10.5
Agree (4)	101	25.3
Strongly Agree (5)	109	27.3
Very Strongly Agree (6)	102	25.5
No Response	5	1.3
Average Response Score	4.35/ 6.00	

Table 4.45 presents the frequencies and percentages for statement 6 " I have received training to help me integrate science, technology, engineering and mathematics". About two-third of participants chose 'agree' or above with the statement. In other words, the a good number of the participants have received training on how to integrate STEM disciplines in their teaching. The mean score was a 3.4, slightly below the agree option.

Table 4.45

Frequency Table for Statement 6

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	98	24.5
Strongly Disagree (2)	19	4.8
Disagree (3)	67	16.8
Agree (4)	85	21.3
Strongly Agree (5)	80	20.0
Very Strongly Agree (6)	47	11.8
No Response	4	1.0
Average Response Score	3.4 /6.00	

Table 4.46 presents the frequencies and percentages for statement 7 “I have engineering and technology lab equipment in my science lab and/or classroom”. The responses among the the teachers were scattered. Although half of the teachers responded that they have enough engineering and technology lab equipment in their science lab to incorporate STEM in their classrooms; rest half of the teachers don’t comply with it. Following those, the average response was 3.13, just above ‘disagree’.

Table 4.46

Frequency Table for Statement 7

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	116	29.0
Strongly Disagree (2)	48	12.0

Disagree (3)	43	10.8
Agree (4)	77	19.3
Strongly Agree (5)	65	16.3
Very Strongly Agree (6)	46	11.5
No Response	5	1.3
Average Response Score	3.13 / 6.00	

Table 4.47 presents the frequencies and percentages for statement 8 “I often provide opportunities to develop a science or engineering project”. 75% percent of the participants chose the ‘agree’, ’strongly agree’ or ‘very strongly agree’ option, with an average score of 3.96 supporting the opportunity to develop a science or engineering project in their science classrooms.

Table 4.47

Frequency Table for Statement 8

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	28	7.0
Strongly Disagree (2)	36	9.0
Disagree (3)	45	11.3
Agree (4)	117	29.3
Strongly Agree (5)	109	27.3
Very Strongly Agree (6)	56	14.0
No Response	9	2.3
Average Response Score	3.96 / 6.00	

Table 4.48 presents the frequencies and percentages for statement 9 “I have been trained in how to change my classroom to a STEM classroom”. The responses among the the teachers were split into half. Almost half of the participants responded ‘agree’ and above and rest of the half ‘disagree’ and below with the statement. Following those, the average response was 3.09, just above ‘disagree’.

Table 4.48

Frequency Table for Statement 9

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	94	23.5
Strongly Disagree (2)	37	9.3
Disagree (3)	87	21.8
Agree (4)	91	22.8
Strongly Agree (5)	48	12.0
Very Strongly Agree (6)	34	8.5
No Response	9	2.3
Average Response Score	3.09 / 6.00	

Table 4.49 presents the frequencies and percentages for statement 10 “I think current in-service training is good enough to help teachers implement STEM in classrooms.”. The responses among the the teachers were almost split into half. More than half of the participants responded ‘disagree’ and below and rest of the half ‘agree’ and above with the statement. Following those, the average response was 3.31, above

‘disagree’. In other words, teachers responded that they present professional development is not equally effective for all teachers.

Table 4.49

Frequency Table for Statement 10

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	100	25.0
Strongly Disagree (2)	34	8.5
Disagree (3)	67	16.8
Agree (4)	65	16.3
Strongly Agree (5)	56	14.0
Very Strongly Agree (6)	69	17.3
No Response	9	2.3
Average Response Score	3.31 / 6.00	

Table 4.50 presents the frequencies and percentages for statement 11 “I think the present curriculum is good enough to permit teachers to use STEM in classrooms”. The responses among the the teachers were almost split into half. More than half of the participants responded ‘disagree’ and below and rest of the half ‘agree’ and above with the statement. The average response was 3.05, just above ‘disagree’ which reflects that the present curriculum isn’t equally supported by all teachers for implementing STEM in their classrooms.

Table 4.50

Frequency Table for Statement 11

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	112	27.9
Strongly Disagree (2)	43	10.7
Disagree (3)	62	15.5
Agree (4)	74	18.5
Strongly Agree (5)	68	17.0
Very Strongly Agree (6)	33	8.2
No Response	8	2.0
Average Response Score	3.05 / 6.00	

Table 4.51 presents the frequencies and percentages for statement 12 “I often do STEM activities with my students”. Most participants ‘agree’, ‘strongly agree’ or ‘very strongly agree’ with the statement. This indicates participants do STEM activities with their students to incorporate STEM in their classroom. An average response score of 4.03 confirms STEM practices in their classrooms.

Table 4.51

Frequency Table for Statement 12

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	37	9.2
Strongly Disagree (2)	19	4.7
Disagree (3)	47	11.7

Agree (4)	106	26.4
Strongly Agree (5)	110	27.4
Very Strongly Agree (6)	70	17.5
No Response	11	2.8
Average Response Score	4.03 / 6.00	

Table 4.52 presents the frequencies and percentages for statement 13 "I teach using problem solving and critical thinking". All participants chose either 'agree', 'strongly agree' or 'very strongly agree' with the statement. The mean response score was a 4.64, more than 'agree'. In other words, teachers are used to practice problem solving and critical thinking skills in their STEM lessons and science classrooms.

Table 4.52

Frequency Table for Statement 13

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	6	1.0
Strongly Disagree (2)	4	2.2
Disagree (3)	35	8.7
Agree (4)	110	27.5
Strongly Agree (5)	129	32.2
Very Strongly Agree (6)	107	26.7
No Response	6	1.5
Average Response Score	4.64 / 6.00	

Table 4.53 presents the frequencies and percentages for statement 14 “I encourage students to apply science and technology across disciplines”. All participants chose either ‘agree’, ’strongly agree’ or ‘very strongly agree’ with the statement. An average response score of 5.0 provides evidence that participants were more likely to encourage students to apply science and technology across disciplines in their classrooms.

Table 4.53

Frequency Table for Statement 14

Answer Choices	Frequencies and Percentages	
	Teacher	Percentage (%)
Very Strongly Disagree (1)	3	0.8
Strongly Disagree (2)	1	0.3
Disagree (3)	9	2.3
Agree (4)	74	18.5
Strongly Agree (5)	147	36.8
Very Strongly Agree (6)	156	39.0
No Response	10	2.5
Average Response Score	5 / 6.00	

Table 4.54 presents the frequencies and percentages for statement 15 “I encourage students to find STEM jobs”. Most of the participants chose ‘agree’, ‘strongly agree’ or ‘very strongly agree’ with the statement encouraging students to find STEM jobs. The average response score was a 5.02 confirms many participants were at the ‘agree’ and above.

Table 4.54

Frequency Table for Statement 15

Answer Choices	Frequencies and Percentages	
	Teacher	Percentages (%)
Very Strongly Disagree (1)	8	2.5
Strongly Disagree (2)	1	2.0
Disagree (3)	9	0.2
Agree (4)	66	16.5
Strongly Agree (5)	129	32.2
Very Strongly Agree (6)	177	44.1
No Response	10	44.1
Average Response Score	5.02 / 6.00	

Table 4.55 Survey Summary (Part C)

Science, Technology, Engineering, and Mathematics Education

No.	Items	Mean (6.00)	Median	Mode	Standard Deviation (S.D.)
1	I understand what is meant by "STEM".	3.97	4.00	6	1.76
2	I try to integrate engineering with science in lessons.	4.32	4.50	5	1.36
3	I try to integrate mathematics with science in lessons.	4.56	5.00	4	1.34
4	I try to integrate technology with science in lessons.	4.64	5.00	6	1.39
5	I try to teach science and integrate at least two other of the following disciplines- engineering, technology or mathematics.	4.35	5.00	5	1.51

6	I have received training to help me integrate science, technology, engineering and mathematics	3.40	4.00	1	1.74
7	I have engineering and technology lab equipment in my science lab and/or classroom	3.13	3.00	1	1.80
8	I often provide opportunities to develop a science or engineering project	3.96	4.00	4	1.51
9	I have been trained in how to change my classroom to a STEM classroom	3.09	3.00	1	1.64
10	I think current in-service training is good enough to help teachers implement STEM in classrooms.	3.31	3.00	1	1.86
11	I think the present curriculum is good enough to permit teachers to use STEM in classrooms	3.05	3.00	1	1.73
12	I often do STEM activities with my students	4.03	4.00	5	1.60
13	I teach using problem solving and critical thinking.	4.64	5.00	5	1.22
14	I encourage students to apply science and technology across disciplines.	5.00	5.00	6	1.19
15	I encourage students to find STEM jobs.	5.02	5.00	6	1.29

CHAPTER FIVE

Conclusion and Discussion

Conclusion

Demographics of Participants in the Study

This study surveyed 400 teachers in total. Of those 400 teachers, 5 were Head Teachers, 312 were science teachers, and 83 identified as "other" teachers. The other teacher category included roles such as mathematics or any teacher with a responsibility to teach science in lower secondary level.

Of the 400 surveyed participants, 341 or 82.25% conducted their primary teaching in Bengali while only 59 or 14.75% primarily taught the English curriculum. The participants in this study were predominantly male (272) at 68% and (125) only 31.35% being female. Several teachers chose not to identify themselves on this question. The participants in this study ranged in age from 24 to 50+ years old. 24.25% of the participants fell into the 30-34 age range. The rest of the age range categories were fairly evenly distributed from 11% to 18% in each category.

According to the question regarding years of teaching experience, the largest group of teachers (33.75%) responded that they were in their 0-5 years of teaching. This is interesting for the results in section two and three as 33.75% of the respondents would also be recently freshly out of college and represent many of the methods of teaching that they learned while in school. The rest of the participants responded fairly evenly in the experience categories, grouping by five years, from 12.5% in 16-20 years of teaching experience to 19.25% in 6-10 years of experience.

The respondents had varied teaching positions as recorded in the survey. 145 participants (36.25%) stated that they were Assistant Teachers. 18 responded (4.5%) that they were Junior Teachers. The largest category resulting in 154 respondents (38.5%) reported that they were Senior Teachers. 44 participants responded that they were Head Teachers or Assistant Head Teachers. 20 respondents were faculty at the local university. Nine respondents who did not identify their teaching positions.

Interestingly, when the education of the participants was explored, the entire group nearly 75% held a Master's degree or higher. Specifically, four respondents had Ph.D.'s, eight respondents had Masters in Philosophy, 284 or 71% held a Master's Degree, 52 only held a four year Bachelor's Degree, 48 held a three year Bachelor's Degree and four people did not respond.

The participants were asked to identify the primary subject of their Bachelor's Degree. 236 of the participants (59%) held a B.S. in Science, eight held a B.S. in Social Science, 14 held a B.S. in Arts, and 28 held a B.S. in Education. It seemed that there was some confusion in this question as 106 participants (26%) categorized themselves as other. Of the participants who held a B.S. in Science, the majority of the respondents held their specialty in the area of Physical Science, Chemistry had 69 teachers (17.25%) and Physics had 70 teachers (17.5%). 66 teachers reported that they held their specialty in the Life Science with 25 teachers (6.25%) in Botany and 41 teachers (10.25%) in

Zoology. 20 (5%) reported their degree in Science Education. Again, there was a large group of teachers that did not identify their degree in a particular science field 175 or 41.5%.

The final questions pertained to those who held a Master's Degree. 299 participants (74.75%) stated that they held a Master's Degree. When the subject of the Master's Degree was explored, the science specialty identification was similar to those with the Bachelor's Degree distinctions. At the Master's Degree level, the majority of participants identified with a Life Science emphasis with 57 teachers (14.25%) in Botany and 52 teachers (18%) identifying in Zoology. The Physical Science represented with 48 teachers (12%) working in Chemistry and 44 teachers (11%) working in Physics. There were 80 teachers (20%) who Master's Degree was in Science Education and again, 72 teachers (18%) identified as a specialty outside of science.

Science Teachers Beliefs and Practices in Bangladesh

Part two of the survey asked for teachers to explore their science teaching beliefs and practices on current science education practices and inquiry teaching. There were four basic categories that all of the questions fell under. These categories included, curriculum, instruction, assessment, and professional development. This entire section used a six point Likert scale of Very Strongly Disagree (1), Strongly Disagree (2), Disagree (3), Agree (4), Strongly Agree (5), and Very Strongly Agree (6).

Using inquiry in the science curriculum in Bangladesh

The first set of the statement in the survey (questions 1-6) explored the understanding and use of inquiry in the curriculum and teaching that teachers used in their instruction in Bangladesh. Statement one and twenty gathered information on teachers perception on Inquiry and what they think about present lower secondary science curriculum to practice Inquiry. Statement one asked the participants if they understood what is meant by "inquiry teaching." A very small percentage of respondents 1.5% answered on the disagree side of the scale. Two teachers said they Very Strongly Disagree, two more teachers reported that they Strongly Disagree, and two other teachers just Disagreed. 97.45 percent of the teachers recorded a positive or Agreement with this statement. 174 teachers out of 400 (43.5%) reported that they 'very strongly agree' with this statement, 134 teachers out of 400 (33.4%) 'strongly agreed' with this statement and 82 teachers out of 400 (20.5%) 'agreed' with this statement.

On the other hand, statement twenty asked about the lower secondary science curriculum effectiveness to practice inquiry in the science classrooms. 33% of the participants responded that present lower secondary science curriculum in not good enough and lower to implement inquiry in the science classroom, rest of two-third agreed that present curriculum is good for to implement inquiry. Out of this 66% or 253 participants (out of 400), 106 (out of 400) 'very strongly agreed' that present science curriculum is good enough for implementing inquiry. On the other hand, 14% or 56 participants (out of 400) 'very strongly disagree' with this statement of curriculum effectiveness. Therefore, statement one about understating inquiry where 97 percent participants 'agree' or above. Therefore, the existing lower secondary science curriculum effectiveness is under individual disagreement, which requires further discussion.

Science Instructional Strategies Practiced in Bangladesh

The role of instruction was another focus of the survey statements. The statements collected data on teachers' current instructional strategies practices and the role of inquiry in science education.

Teaching Continuum

One of the primary foci of the study was to find the responses from the participants about currents instructional practices such as the use of lecture, investigation, demonstration methods in the science classroom. As well as what are the inquiry components practices such as using learning cycle, using probe questions, collecting data, applying learning in new context, and working with groups or individuals.

The study found that there are certain numbers of teachers still use direct instruction methods such as lecturing, demonstration or investigation (limited level of inquiry) science teaching method. Statement two asked about current level of inquiry practices in their classrooms. 93% participants have either agreed, strongly agree or very strongly agree. Out of this 93%, 43% participants responded that they were practicing very strongly. A similar number of participants have also responded the use of hands-on materials.

In addition to inquiry the science teachers are also practicing other instructional strategies such as lecturing, demonstration, and investigation (limited level of inquiry) methods. The survey found a similar response from the participants about traditional direction instruction. The survey found that most of the teachers (75 percent lecture method, 90 percent demonstration method, 99 percent investigation) are practicing direct instruction over the year. In other words, out of four hundred participants at least three hundred participants regularly use direction instruction over the year in their science classrooms. Their responses were also verified by the other statement where they responded that 90 percent participants practice data collection methods when they practice investigation or demonstration method.

Bangladesh uses a traditional British based science curriculum that heavily textbook based. It is no exception but the education system uses textbook widely as instructional tool. This study initiated to find the percentage of the textbook based in their science teaching. The responses from the participants were split into almost half and half. Out of four hundred participants, two hundred and seven participants (around 50%) replied that they relied on the textbook. However, rest of them replied that they don't used textbook as their primary tools for science teaching. Another statement just replied opposite to this practice. Statement twenty-four was according to memorization practice in science education. The participants reported that they do not encourage students to learn science by using textbook; 333 participants (out of 400) 'disagree' to 'very strongly disagree' to learn science by memorization and using science textbooks. Only 13.3

percent participants either ‘agree’ to ‘very strongly agree’ on memorization based science education held in their classrooms.

The used scientific equipment was one of the major key components of successful science education. Statement twenty one of the survey, “I think schools have enough equipment and required facilities to practice inquiry in teaching”, was how much equipment and facilities they have to correct inquiry in their science classroom. Statement twenty one found scattered response form the participants. On the six level Likert-scale, all of them responded between ten to twenty-five percent. Out of four hundred participants, ninety five participants disagree and 199 participants (out of 400) disagreed with this statement.

This study also tried to find the use of supplemental teaching materials support such as computer, different kind of software or use of the internet. Statement seven and sixteen focused on use of the supplemental materials in science classrooms. For both of the statements, more than 85 percent participants responded that they use technology in their science classrooms to enhance science teaching-learning. Additionally, out of four hundred participants at least 376 participants were using the internet as strong supplementary instructional materials in science classrooms. It also reflects the statement seven is “I use technology such as computers, PowerPoint software, tablets, the internet, or videos to enhance student learning” where 335 participants are using the computer and computer based software in their science classrooms.

Student learning is enhanced by the application of the experienced knowledge. The study utilized two statements on the application of studied knowledge. Statement fourteen, fifteen, and seventeen surveyed the participants' opinion on the opportunity of students' process skills, problem-solving and critical thinking skills, and multi-modal presentation. The participants reported that they were practicing and assessing science and engineering in their classrooms. More than 90% percent participants agreed or above that they provide the opportunity for the students to apply their experienced scientific knowledge in a new science and engineering context which help them to practice their process, problem-solving and critical thinking skills, and through multi-modal presentation. Statement fifteen and seventeen supported the teachers' practice. Statement fifteen found that more than 90 percent participants or 366 participants reported they encourage the students to use the multi-modal presentation such as graph or table. On the other hand, statement seventeen reported on process skills or problem-solving skills. More than 90 percent teachers responded that they were practicing science process skills and problem-solving skills in their science skills.

Statement 23 was "I know about the learning cycle as a way of teaching inquiry science". The 'Learning Cycle' is one of the most widely used inquiry-based science teaching method. Statement twenty-third was on about teachers knowledge and practices on the 'learning cycle'. Two-third of the participants (336 persons out of 400) reported that they know and practice 'learning cycle' in their science classrooms. Another aspect of science instruction is students participation which is also essential for inquiry-based instruction. 359 participants responded ‘agreed’ and above.

Science Education Assessment Practiced in Bangladesh

The survey utilized several science assessment statements to find teachers current evaluation practices. Additionally, about their teachers’ responsibility on students learning. The participants responded that they were practicing formative assessment to assess students’ science process and problem-solving skills. More than 80 percent or 223 participants agreed or above with the statement. In statement twenty-five, the participants reported that teacher should not be responsible for students learning science. This statement reflected the formative assessment and teachers’ accountability, which is opposite to the first statement. Out of four hundred participants, 73 (18.3%) teachers ‘very strongly disagree', 37 (9.8%) ‘strongly disagree’, 67 (16.8%) ‘disagree’, 100 (25%) ‘agree’, 71 (17.0%) ‘strongly agree’, 45 (11.3%) ‘very strongly agree’ and 5 (1.3%) did not respond the statement.

Science Education Professional Development in Bangladesh

Teacher preparation is one of the four components of the education system (NRC, 2012). The survey utilized statement eighteen, nineteen, twenty-two, twenty five, twenty-six to understand science teachers professional practices and impact in their profession.

Statement eighteen and nineteen focused on whether the teachers had formal training on inquiry-based teaching and how the tearers are helping students to practice inquiry in their science classrooms. Statement eighteen found that around 60 percent participants reported they had training on teaching through inquiry. However, 40 percent rest of the participants reported that they do not have any in-service professional development on Inquiry methods.

Statement twenty-five and twenty-six focused on teachers accountability with inquiry practice. Statement twenty-five was on the relation between student success and teachers performance. The participants reported quite split answers. 216 participants (out of 400) reported ‘agree’ to ‘very strongly agree’ and 179 participants (Out of 400) reported ‘disagree’ to ‘very strongly disagree’. However, in statement twenty-six, “I think students’ learning in science is directly related to their teacher’s effectiveness in science teaching”, responses was more positive. In other words, the participants emphasis on more teachers’ responsibility for students learning.

Another focus of the survey was how the teachers felt about the administrators role in implement the inquiry in the classrooms. Question twenty-two, “Administrators can help teachers begin to practice new science methods such as inquiry in classrooms” reported that 90 percent participants (367 out of 400) ‘agree’ (4.0) to ‘very strongly agree’ (6.0). Therefore, administrators could make a significant difference in teachers practice in the classrooms.

STEM Education Perceptions and STEM Practices (Part C)

Part three of the survey was science teachers' STEM education perceptions and practices. There were four basic categories that all of the questions fell under. These categories included, curriculum, instruction, assessment, and professional development. This entire section used a six point Likert scale of Very Strongly Disagree (1), Strongly Disagree (2), Disagree (3), Agree (4), Strongly Agree (5), and Very Strongly Agree (6).

Understanding STEM in the Curriculum (questions 1-5)

The initiated questions of this section were on understanding STEM education and it's prospect. One-third of the participants who marked 'agree' to 'very strongly agree', have responded that they understand STEM. However, the average response is 3.97 out of 6.00 which is between 'disagree' (3.00) and 'agree' (4.00). In other words, the respondents understanding and knowledge about 'STEM' seems to be minimal at best.

STEM is the integration of two or more disciplines—science, technology, engineering, and mathematics (NRC, 2014; Bybee, 2013). A number of survey statements were based on teachers' STEM integration knowledge. Statement two was on integrating engineering with science, statement three on integrating mathematics with science, statement four on integrating technology with science, and statement five on integrating science and at least two other of the disciplines—engineering, technology or mathematics in a lesson. The participants responded 'agree' to 'very strongly agree' that more than 60 percent of the lesson integrate science with engineering; 90% of the participants responded, ‘agree’ to ‘very strongly agree’ that they were integrating science with mathematics; 85% of the participants responded, ‘agree’ to ‘very strongly agree’, that they integrate science with technology. Statement five found that 75 percent participants ‘agree’ to ‘very strongly agree’ on integrating science with at least two other STEM disciplines. All these responses reflect synchronized STEM integration.

In contrary, the participants responded that the present curriculum was not good enough to implement STEM in science classrooms. More than half of the participants responded ‘disagree’ and below and the other half of the participants reported that ‘agree’ to ‘very strongly agree.’ The average response was 3.05, demonstrate a split of teacher preparation which reflects that the present curriculum isn’t equally supported by all teachers for implementing STEM in their classrooms.

STEM Instructional Strategies

STEM instructional strategies was another focus of the survey. Statement seven, eight and nine focused on available instructional materials, teacher preparation and classroom practices. Statement seven found that the participants think that current STEM laboratory materials were not sufficient to implement STEM in science classrooms. The average response 3.13 (out of 6.0) also reflected the lack of STEM materials availability.

Statement eight found that 75 percent participants utilized science or engineering projects as an instructional strategies in their science classrooms. However, the average scored 3.95 (out of 6.0) which reflects strong disagreement of 25% of the participants.

Statement twelve found similar response offer by the participants in their classrooms. However, their average response is 4.03 (out of 6.0) which reflect little bit less disagreement than previous instructional practices.

Another focus of the survey on STEM instructional practices was teachers' preparation for bringing STEM into the science classroom. The participants average responses was 3.09 (out of 6.0) which reflects that they do not have adequate professional preparation and training on STEM education. The detail responses was 94 out of 400 (23.5%) 'very strongly disagree', 37 out of 400 (9.3%) 'strongly disagree', 87 out of 400 (21.8%) 'disagree', 91 out of 400 (22.8%) 'agree', 48 out of 400 (12.0%) 'strongly agree', 34 out of 400 (8.5%) 'very strongly agree' and 9 out of 400 (2.3%) did not respond. The overall responses among the participants and their STEM education practices were not similar.

One of the major focus of STEM education is crosscutting concepts or inter-disciplinary practice. Statement fourteen collected data on crosscutting concepts which reflected that the teachers encourage the students (5.0 out of 6.0) to apply their experienced knowledge in other disciplines.

STEM Professional Development

STEM based professional development was another focus of the survey. The survey questions were focused on their access, quality and practice of in-service and pre-service teacher preparation programs. Statement six found that the participants do not receive any training on STEM education. The average response is 3.4 out of 6.0 which is between 'agree' (3.0) and 'disagree' (4.0). Although 201 out 400 participants reported 'agree'(4.0) to 'very strongly agree' (6.0), 98 participants (24.5%) 'very strongly disagree' (1). Statement ten collected data on current STEM professional development quality. The study found that the participants split half and half with their response on STEM based professional development. Around fifty percent (190 participants out of 400) participants reported that present professional development in traditional not STEM based.

On the other hand, Statement nine reported the current level practice of the professional development. The statement found that the average response of the statement is 3.09 which is just above of 'disagree' (3.0 out of 6.0). Whatever they have been trained or not to implement STEM education, they are not comfortable or have not learned enough to change the science classrooms into STEM classrooms.

Discussion

This section will count the findings of the summary to on science teachers beliefs and practices, and STEM education in Bangladesh to achieve 21st century science education challenges.

Science Teachers Beliefs and Practices in Bangladesh

The survey collected data on current science teachers beliefs and practices. The analyzed data discussed by under following themes— using inquiry in science curriculum in Bangladesh, STEM education perceptions and practices, STEM instructional practices, STEM assessment, STEM professional development.

Using inquiry in the science curriculum in Bangladesh

The survey has found that the science teachers understand inquiry-based science education. The present curriculum reflects that The first statement was how much teachers know about inquiry. Supporting this statement, question four asked how much they encourage or inquiry practice in their science classrooms. Among the participants, 93% choosing either 'agree', 'strongly agree' or 'very strongly agree' which reflects that they use Inquiry based teaching methods. However, the educational science practice in Bangladesh implies different scenario.

Although there is a long history of science instructional practices in Bangladesh, there is not enough consistency over time. Although the current science education inherited from the British colony and then from Pakistan, the new initiative started on 1974 by Kudrat-E-Khuda education commission (Tapan, 2010). Following the education efforts, science teaching and science textbooks were adopted in 1981, 1982, and 1983 (Tapan, 2010). However, the level of practices of this education commission and it's evolution was not always acceptable.

The Kudrat-E-Khuda Education Commission first enhanced on inquiry-based science education through out primary and secondary science curriculum in Bangladesh. However, due to different political issues, lack of preparation, and practice the curriculum was altered and fell away from the inquiry focus. The primary purpose of this study was to search for the current level of inquiry practices in science classroom by the science teachers.

To begin, the national primary and secondary science curriculum have been encouraging inquiry since 1974 as a result of the “Dr. Kudart-E-Khuda education commission” (NCTB, 1974). Following this recommendation, inquiry-based textbooks entitled “ Let's do science” was introduced in the 1980s. However, the inquiry-based science curriculum was aborted for lack of teachers and parents cooperation (Tapan, 2000). Tapan also mentioned that the assessment system was not aligned with the instruction without the new science curriculum. Additionally, Teachers are unable to implement inquiry-based science for lack of professional development training and equipment/ materials. Furthermore, parents were not clear about their children’s science learning outcomes brought upon the traditional assessment system. Since the traditional science curriculum was content based, memorization focused, and direct instruction, parents, were not convinced about the new inquiry-based science education. As a consequence, NCTB reintroduced content-based science curriculum again in 1994. However, they introduced 25% investigation based laboratory work from 9th-grade science subjects up to 12th grade. The implementation of the investigation-based laboratory method more than 20 years later, still learners a list to be done.

From this discussion, Both science teachers inquiry practice in classroom and administrators responsibilities is questionable due to lack of introducing appropriate science assessment and convincing the parents about its potential success and learning science. Therefore, it is necessary to overcome these challenges to incorporate inquiry in science education. Although new Education Policy (2010) and new science curriculum (2012) has recommended inquiry-based science education in Bangladesh, there has been still questions recently the previous shortcomings and implementation of the inquiry portion of the curriculum.

The two principal challenges for current science curriculum are: (a) the new science textbook reduced a significant amount of content to introduce and practice inquiry (NCTB, 2012). As a result, the teachers are still following rote direct instruction and finishing up the content within a structure period of time. (b) The second challenges resolves around the are assessment system. Although the ministry of education has been trying to introduce inquiry-based instruction, they did not align the assessment system with inquiry based science instruction. As a result, the current practice is “Creative Assessment/ Srijonshil” assessment system. However, assessment should be considered as part of the inquiry-based assessment where assessment is found as to enhance student learning rather than testing only created knowledge. After all, these successes depend on science teachers readiness to transform their teaching and practices in the classrooms.

Taking Science to School recommended a range of experiences to enhance science learning among students (NRC, 2007). The report has identified four strands of proficiency for successful science learning: (1) Knowing, using, and interpreting scientific explanations of natural world, (2) Generating and evaluating scientific evidence and explanations, (3) Understanding the nature and development of scientific knowledge, (4) Participating productively in scientific practices and discourse (p.36).

Science education in Bangladesh needs similar reformation to enhance science learning among the students. To achieve the scientific proficiency among the students, science curriculum, instruction, assessment and professional development should focus on these four strands. These should be also included in the education policies to enhance the overall reformation process.

National Science Education Policy, 2009

The National Education Policy (2009) stated that the goal of science education is to understand science through using experiment, observation, and mathematical logic. The blueprint has inferred that the proposed science curriculum will be able to nourish students habits of mind or inquisitiveness and help the society move forward though utilizing different technology. The ministry of education has proposed different strategies for primary and secondary science education.

The education policymakers in Bangladesh also call for a change for popularizing math and science across the country (NCTB, 2009). The education committee recommended that Science Fair or Math Olympiad could be one of the best ways to popularize these subjects. The education committee also recommended that Science Fair or Math Olympiad should be organized by each school and national level.

National Education Policy (2009) of Bangladesh supported science education in-service teacher training program from primary to the university levels. This committee also urged for modern science and technological uses in science classrooms to help the students to acquire new knowledge and experiences.

National Education Policy (2009) emphasized establishing new science laboratories up to Upazillas or Suburbs. They also recommended that these kind of infrastructures will be using different educational institutes based on their needs and availability. Therefore, it is inevitable to develop a reformation plan based on new education policy.

STEM Education Perceptions and STEM Practices

Understanding STEM in the Science Curriculum in Bangladesh

The new science education vision of STEM education has been redefined with science and engineering focus. The new science education vision emphasized compelling scientific questions and the pursuit of the joy of discovery and invention (NRC, 2015). This section of the study has been designed to find out the teachers' readiness to implement new science education or STEM education vision.

There were five statements on STEM education vision and curriculum in this study. The participates reported that they understand what STEM means and how much they are integrating the STEM disciplines in their science classrooms. Two-third (66%) of the participants stated that they know what does STEM means, and one-third of the participants do not have any idea about STEM. However, majority of the participants reported that they are integrating STEM disciplines in their science classrooms.

Science Education Policy and Practice in Bangladesh

Although the science education policy and science curricula recommended consideration of other disciplines such as math (2010), there is no particular framework or guideline in science education policy to integrate more than one subject or practice along with other STEM disciplines. Therefore, the participants' responses require more explanation to justify their claims about STEM education.

The National Education Policy (2010) pointed out the current science education vision and mission for science education (MoE, 2010). The education policy has described science education goals, objectives, and strategies for different education levels. The education policy stated the overall goals and objectives of science education are to understand nature, human inquisitive ability, and utilizing technology to move society forward by using scientific knowledge. Therefore, the ministry of education recommended that science education should prepare students to align with international science standards with an emphasis on developing their talent over their school years, practice of knowledge, and nourishing natural world and creativity.

The primary education (1st to 5th grade) in Bangladesh specifically designed to introduce science at the beginning stage of education system. Although the integrated primary education considered up to fifth grade, they recommended integrated science education up to eighth grade. There is a separate science textbook from third grade to eighth. Besides this, the education policy recommended to emphasize mathematics in science due to their close relationship. The Ministry of Education also encouraged recruiting mathematics graduates to enhance science learning. They also encouraged the emphasis on science and mathematics practical learning. The science teaching methods also require the inquiry of different branches of knowledge in science with problem-solving skills that apply to real life situations.

The education policy (2010) also recommended out-of-school science programs such as science fair or Math Olympiad to popularize science and mathematics among the students. The programs would be included along with annual sports or cultural week. The education policy also recommended national championship to make them competitive and popular.

International Science Education Trend, Movement, and Evolution

Science education in the U.S. has been evolving over time with research like as *Science for All*, *Scientific Literacy*, *Science, Technology, and Society (STS)*, *Benchmarks for Science literacy, National Science Education Standards,* and *Science, Technology, Engineering and Mathematics (STEM) Education*. These science education initiatives have been evolving based on innovation, society, and future expectations (AAAS, 1989; NRC, 1996; NCTB, 1974; NCTB, 1994; NCTB, 2012). Science education in Bangladesh has been following some level of the world trends over the years as well. However, they have been not implemented successfully according to the plan or aborted reformation for different socio-political reasons or lack of expertise (NCTB, 1974; NCTB, 1986; NCTB, 1994; NCTB, 2012). The current education policy (2010) and science curricula (2012) focuses on inquiry based science education. Additionally, they have introduced computer and Information and Communication Technology (ICT) based courses to overcome 21st century challenges (NCTB, 1994; NCTB, 2012).

To overcome the science education evolving challenges, STEM education has introduced, in the United States, through the *A Framework for K-12 Science Education* since 2012. There are a range of science standards, *Next Generation Science Standards,* has been inaugurated following the release *framework.* The new science education vision in the U.S. emphasized on not only the *content* of science but also the *doing* of science or practices (NRC, 2015). In others words, the new science education vision focused on not only learning scientific facts and concepts but also students habits of mind, science and engineering practices and skills to connect with real life situation and new context. Related to contemporary science education reformation, there are many things that Bangladesh can learn from the current science education research and NGSS from the U.S.

Tentative STEM based Integration in Science Curriculum for Bangladesh

Following the National Education Policy, the National Curriculum & Textbook Board (NCTB) developed latest secondary science curriculum in 2012. The science curriculum articulated the following sections: curriculum development rationale, curriculum outline and characteristics, science teaching-learning methods and strategies, and assessment (NCTB, 2012). National secondary science curriculum in Bangladesh is highly discipline separated, content-based, textbook focused, assessment focused and highly centralized. As mentioned earlier, lower secondary is six to eighth grade, science curriculum is integrated among the other science disciplines (Siddique, 2008). Although there was an initiative by the NCTB in 2006 to implement Unitrack Curriculum in secondary level (no streaming until 11th grade) to reduce content emphasis, the curriculum was reject by the different scientist and university faculty members claiming the content was less than acceptable by traditional members.

To transform the traditional science education to STEM education, Bangladesh will need to undergo references situations to the U.S.. The United States is one of the forerunner in STEM education nations across the world. Although the United States is highly decentralized education system in the world, it has been developing and implementing STEM education programs across the country.

At the beginning of this process for the U.S., STEM education is an evolving result of “Project 2061” which immersed in 1985 (AAAS, 1985). The Project started this historical initiative with “Science for All” caused by the “Sputnik” controversy also helped the country to focused on strong content based science curriculum across the science classrooms.

For Bangladesh, the transformation process may not be similar but the lesson could be exemplary. Science education in Bangladesh is highly content focused and assessment mostly to prepare students in Bangladesh for post-secondary education and professional jobs. The national science curriculum in Bangladesh has had some transition towards Inquiry teaching such as of the course grading based on science labs. However, the laboratory method integration was not accomplished. One reason for this is that, there is not science education framework other than national education policy or science curriculum. The science education framework is crucial to build a sustainable academic program. When done properly, the national curriculum may provide the opportunity for policymakers and educators to understand and practice contemporary science education with the reformed constructed framework.

Another challenge for the science education in Bangladesh is translating curriculum into practice for educators. The curriculum includes many points includes many points including abstract blueprint and science as a discipline is a scientific area of knowledge. Therefore, it's really challenging for the educators to bridge between science and curriculum.

STEM Instructional Strategies Practices

STEM based instruction was another focus of this study. There were number of statements were utilized for STEM based instruction. The statements reported by the participants were on interdisciplinary practices, use of effective laboratory equipment, effective training for new instructional practice, use of different kinds of innovative instruction such as problem based method or project based method, and application based instructional method.

The current secondary science education recommended that studying science should include mathematics (NCTB, 2012). Therefore, they have recommended that math graduates should be teaching math in secondary level. This is a first step in open the door to introducing STEM curriculum in secondary level win Bangladesh. The education policy has identified the importance of Science and Maths integration which should be incorporated in secondary curriculum, instructional design, assessment, and practices. The current assessment system does not take into consideration, this kind of interdisciplinary integration and practices.

The education policy (2009) also recommended that science textbooks and teaching methods should be invigorated with problem solving skills that students can apply in real life situations (p.38). The national education policy calls for the importance of hands-on activities stetting "without the practical classes; science education becomes useless". The policy makers are requiring hands-on knowledge for both science and maths (NCTB, 2009).

From this study, participants reported that they are practicing STEM based disciplinary integration or interdisciplinary instructional practices; participants reported that they do not have enough laboratory equipment to practice STEM based instruction. The current science curriculum is not enough for teachers to practice such kind of integrated instructional practices as they have not received any kind of instructional training to integrate STEM based instruction in their science classrooms.

The study has found that the participants reported on instructional practices in a varied manner. For example, the average participants reported equally agreed and disagreed, or neutral response about teacher training or laboratory equipment to implement new STEM based education or instruction. However, the participants have reported that they have been practicing integrated STEM education in their science teaching, problem or project based instruction in their classroom. Besides this, they have reported that the current science curriculum is not good enough to do such kind of integrated instructional practices.

National Science Education Instructional Policy and Practices

The NCTB (2012) published new science curriculum and textbooks for lower secondary, secondary, and higher secondary science education. The new science curriculum did not design any specific laboratory assessment for lower secondary education but twenty five percent of the grade for all secondary science subjects is laboratory based assessment, as well as twenty five percent for all higher secondary science subjects. However, all the science subjects have allocated 25% of the grade for investigation method. Currently, teachers in Bangladesh use predominantly lecture based teaching methods (Mojumder, 2015).

International Science Education Instruction Trend

The evolving science education has been improving over time such as Science for All, Scientific Literacy, Science, Technology, and Society (STS), and Science, Technology, Engineering and Mathematics (STEM). All these science education initiatives have been evolving based on innovation, society, and future expectations (AAAS, 1986; NRC, 1996; NCTB, 1974; NCTB, 1994; NCTB, 2012). The science instruction also evolve over time based on new education policy, framework, curriculum, and practice. However, the main focus of all these is to transfer the scientific experiences into scientific learning.

Expected Science Instructional Shift for Bangladesh

Although Bangladesh has launched several science education enhancement project over time, most of the cases they have aborted or directed their direction for political or lack of expertise.

Traditional secondary science instruction in Bangladesh is mostly textbook based with 25% laboratory work. However, the lower secondary science instruction doesn’t have such opportunities. On the other hand, for lack of or implementation challenges there are not enough opportunities to overcome the instructional challenges.

The present world vision of science education has enhanced on make science and engineering lively in the classrooms and among the students, pursuing for scientific questions, and the joy of discovery and invention (NRC, 2015).

STEM Assessment

The *framework* has recommended assessment as a means to measure the curriculum and students outcome which reflect student competencies (NRC, 2012). There are number of assessment formal, large-scale standardized, or less formal, classroom-based, assessment methods recommended by the *framework* to achieve new science education vision. Three purposes of educational assessments has mentioned by the *framework* (NRC, 2012; Pellegrino, Chudowsky, and Glaser, 2001)—(1) formative assessment for use in the classroom to assist learning, (2) summative assessment for use at the classroom in large-scale, (3) assessment for program evaluation. There is another type of assessment to evaluate teacher effectiveness. The *framework* has also recommended that all types of assessments should be used to achieve new science vision.

STEM Professional Development

Professional development is one of the four pillar of education system (NRC, 2012). This research found different responses from the teachers that was mixed. The survey science teachers responded about STEM based professional development for implementing STEM in lower secondary classroom both in-service and preservice teacher training programs exist in Bangladesh. Secondary in-service teachers training program by Total Quality Improvement (TQI) project and Secondary Education Sector Improvement Program (SESIP) are currently use in Bangladesh. Two-thirds of the participants responded that they don't have any kind of training to implement STEM education in their classrooms.

Most of the in-service teacher training programs are run by government through different projects or program like SESDP and TQI. One of the major science teachers professional development initiatives run through TQI project such as ICT in education, secondary science education assessment (Srijonshil Assessment), inquiry based science education instruction etc. However, the participants has responded that they have enough knowledge, experience, and training to implement STEM in the classrooms.

New Professional Development Model

Krajcik (2014) has articulated teacher preparation program should consider teachers' professional growth over time, quality infrastructure for professional development, curriculum and technical support to develop and implement professional development; cost-effective, scalable, and accessible model. Duschl, Schweingruber, and Shouse (2007) argues that efficient and well-designed professional development can ensure effective teaching skills which can improve the classroom practice, student learning, desirable and student outcomes. Therefore, it is necessary to build teachers knowledge, skills, practices, and confidence on bringing three-dimensional learning to the classroom.

Recommendation

This part of the chapter will discuss and recommend necessary steps and action plan to incorporate inquiry and STEM-based science education reformation in Bangladesh. Western science education, specifically the U.S., reformation has gone through three consecutive reformation for last sixty years after World War II to ended up to STEM education (Bybee, 1997; NRC, 2012). After World War II, teacher shortage and salaries, science and technological domination from the war, social and economical progression, and Sputnik race required to the United States to launched first contemporary science education reformation (Bybee, 1997). The second reformation held in 1970s to enhance social and economical growth which focused on reforming secondary schools and science education programs. The third reformation held in 1980s based on "A Nation at Risk" that identified the U.S. economic and business weakness compared to the rival countries as Japan, Germany. To overcome these risks, science education improved school programs, curriculum, instructions, and assessments to change nation's classrooms. This classroom reformation ended up to STEM-based science education system.

Bybee recommended five steps science education reformation based on purpose, policy, program, and practice (Bybee, 1993; 1997; 2013). These steps also utilized by the westernized science education reformation for the United States since 1960s. Bangladesh can follow these steps to reform Inquiry and STEM-based science education. Science education in Bangladesh has been going through several reformation process since 1970s, specially for implementing inquiry and STS based science education. Therefore, it could be a privilege for Bangladesh to learn from western science education reformation experiences and enhance their science education reformation.

Education reformation is part of the social reformation process. Contemporary social issues elicit science education transformation as a process of education reformation (Bybee, 1993). Bybee (1993) mentioned that social and historical circumstances are primary influence of science education reformation. Similarly, science education reformation in Bangladesh also depends on contemporary aspects of social and historical circumstances too. On the other hand, basic structure of science education, the aims of science education, and models of curriculum and instruction are also influence science education reformation by social and historical circumstances. That's why science education in Bangladesh requires both structural reformation such as new science teaching model and practice and ponder economic factors, societal factors as reformation process.

Structural Science Education Reformation.

Bybee (1993) recommended five steps science education process. These five steps are: (a) new perception of science education, (b) the establishment of the new perceptions through publications, (c) the elaboration of theoretical constructs of the model, (d) new curriculum materials, (e) implementation of new programs.

New Perceptions of Science Education.

Bybee (1993) stated that new perceptions or reformation emerged when there is a gap between previous and current science teaching is not align with scientists and educators new science and educational innovations. For example, inquiry, STEM-based content and practices, and three-dimensional learning has emerged as the new perceptions in science education (NRC, 1996; NRC, 2012). He (1993) recommended to introduce new perception in science curricula, instruction or textbooks changes as a new perception of reformation process. Research showed that Bangladesh has been trying to introduce inquiry-based science education since 1970s (NCTB, 1974; Tapan, 2010). However, for lack of appropriate reformation plan and initiatives the reformation aborted or erroneous for science educational movement for more than last forty years (Tapan, 2010). At the same time, *Science of All, STS*-based science education, *Scientific Literacy* focused science education new concepts did not sustain in science education reformation. *Content*-based laboratory focused science education implemented since 1996 in

Bangladesh. However, reformation based on new perception become successful by established new curriculum materials and successful implementation (Bybee, 1993). Although Bangladesh tried align national science education reform with international science education movements, there was not successful reformation from inaugurating new perceptions to implementation (NCTB, 1974; NCTB, 1994; NCTB, 2012; Tapan, 2010).

In this circumstances, introducing new perceptions of 21st century science education—inquiry, STEM-based content and practices, and three-dimensional learning should be taken as new perceptions and need adequate preparation and plan to make a successful science education reformation in Bangladesh (Bybee, 2011; NRC, 2012). Bybee (1993) mentioned that new perceptions should make fundamental changes in content, and adequate classroom materials testing before use them in the classroom.

Publications by Leaders for Development of New Vision.

The second step of science education reformation is development of new vision based on new perceptions. Bybee (1993) recommended that new perceptions based on new thoughts and concepts which leads new set of action plan. In this reformation process, new vision incorporate and enhance by and a number of research, articles, literature, curriculum development documents. Therefore, scientists, educators and stakeholders should publish necessary publications based on new perceptions in science education in Bangladesh.

Although science education reformation depends on education policy in Bangladesh, it needs necessary scientific and research background for necessary reformation too. For last fifty years, there are number of reformation based on new perceptions—*Inquiry, Scientific Literacy, Science for All, STS,* and *STEM* in science education internationally. To establish new perception there are wide range of publications need to be published through out the years. Bangladesh needs necessary scientific and researched documents to enhance science education reformation

Policies for Curriculum.

Bybee (1993) recommended development of curriculum policies based on new perceptions and expectations of different publications as third step of science education reformation. The first initiative of curriculum policy is to set up a new science framework for curriculum and instruction. *Theory in Action* (1964) described guidelines for development and coordination of science curriculum: (1) science curriculum should be coordinated among scientists, administrators, teachers, and other community stakeholders, (2) intense study for existing science education programs based on existing resources and research, (3) curriculum should be developed considering entire science education system not for individual grade level or subject, (4) curriculum development personnel should be more knowledgable and expert in their scientific knowledge area, curriculum planning skills, and critical thinking skills, and use of inquiry in teaching science, (5) curriculum organization should be also focused on scientific process as well as around a scientific principles, (6) science curriculum should consider other subjects based on their relationship with science and include all level of planning, (7) teachers should be familiar with curriculum principles and practices of inquiry to bring them to their classrooms and laboratory situations, (8) both the teachers and administrators should work side by side for advancement of the science programs, (9) new curriculum materials should be added to the curriculum based on proper experiment, (10) curriculum evaluation should be part of curriculum development process and should be implemented throughout the development process, (11) curriculum planning is a on-going process which should take evaluation and revision, (12) community should also involve to successful program implementation both financial and moral.

Science Curriculum Reformation in Bangladesh.

Curriculum Development Rationale.

NCTB (2012) introduced new science curriculum under national education policy (NCTB, 2010) in Bangladesh. There are number rationale for developing new science curriculum such as existing science curriculum is not contemporary since existing curriculum developed in 1995; it is inevitable to make this reformation based on national and international social, cultural, economic, political, science and technology, and communication changes. The existing curriculum is highly memorization-based or encourage memorization which also influence lack of inquiry-based hands-on science education. The curriculum rationale also mentioned that existing language curriculum (both Bangla and English) did not cover adequate communicative skills. Moreover, The current practiced science curriculum is not well enough to emphasis on more 21st century workforce and vision 2021 has set up goals to become a mid-income and 21st-century science and information based society. In this circumstances, building a new science curriculum framework is inevitable to enhance this rationales.

Science Curriculum Development Model

Current science curriculum development is an objective-based or product-based model. According to this model there are number of goal and objectives in general, based on disciplines, and based on grade levels. Grade based and discipline based learning outcomes has derived from this goals and objectives. These learning outcomes has also focused on cognitive, psychomotor and affective domains to outline the content, teaching-learning strategies, and assessment strategies. National science curriculum development committee was consist of eight members— national education specialists, subject-specialists, experienced classroom teachers, national curriculum specialists (NCTB, 2012).

Figure: 5. 1 Science Curriculum Development Model

Philosophical Instance of Current Science Curriculum

National science curriculum has recommended to emphasis on constructivism in science education align with other learning theories: Thorndike trial and error theory, Pavlov's conditional reflexive theory, Gestalt theory, Piaget cognitive development theory. The curriculum added that constructivism in science education should cover students previous knowledge, concept, and experiences; teachers should facilitate and create opportunity to develop their own laboratory experiments based on inquiry or a problem, build their experimental design, and classroom discourses. The curriculum also recommended that teachers should refine students experiences and knowledge based on their reflective practices. Teacher should also encourage students to work on groups (NCTB, 2012).

Necessary Reformation of Existing Model.

Based on the current science education practices in Bangladesh, there are number of curriculum policy reformation is necessary to introduce new perceptions. Most of the science education reformation in Bangladesh aborted due to lack of reformation knowledge as well as necessary curriculum policies. One of major shortcomings of current curriculum reformation process is lack of conceptual framework. There were no specific conceptual frameworks were build for any of the science education reformation for last for years. It might be one of the primary failure to narrow down from policy to practice. Tapan (2010) identified the failures are lack of necessary teacher preparation to bring changes into the science classrooms, and parents lack of cooperation and engage on curriculum reformation. Therefore, curriculum policies should be reformed to inform all stakeholders and adequate time for reformation preparation and practices. Additionally, although there are different philosophical shifts has been recommended for reformation, there are necessary inclusion into textbooks, instructions, teaching-learning process, assessment, and professional development for make the successful transformation.

New Curriculum Materials.

New curriculum material development is the fourth step of science education reformation movement recommended by Bybee (1993). Bybee mentioned that new curriculum theories translate into new perceptions, vision, policies, and models. There number of different curriculum materials could be utilize for primary and secondary science education for example— Full Option Science System (FOSS), Engineering for Elementary (EiE). The U.S. science education reformation reformation movements has been using wide range of curriculum materials such as BSCS biology, PSSC physics, CHEM-study chemistry, ESCP earth science.

New Curriculum Documents.

Development of new science curriculum and instructional materials has been major challenges for science education reformation in Bangladesh since 1970s. Science educational materials plan never was not successful except teachers guidebook, instructional manual or limited amount of instructional materials. However, new perceptions demand complete curricular and instructional material support from policy to implementation.

Education system is highly centralized in Bangladesh. One of the common concerns among the educators in different levels is inadequately reformation knowledge. That is why, it is necessary to develop, produce, and distribute, curriculum documents and materials from the stakeholders to the classrooms.

Teacher Development Resources.

Research found that previous science education reformation did not become successful for lack of adequate teacher development and lack of available resources (Tapan, 2010). After successful completion of previous reformation steps, teacher preparation is inevitable for reformation. Therefore, aligning teacher education programs with classroom practice. In this circumstances, new professional development models are necessary to provide the training, instructional resource access, and action research to measure their reformation performances.

Implementation of New Programs

Bybee (1993) mentioned fifth and final step of the reformation process is implementation of the new perception. He stated as the most difficult task that begins with teachers' perceptional change based on reformation. The perceptional changes for Bangladesh are Inquiry and STEM-based science education. These two words are important and should be included and described in science materials, textbooks, articles, research, policies, programs, etc. (Bybee, 1993). He also added that reformation could not be accomplished until the teachers accept and continue to implement inquiry and STEM-based new science education model. Teacher preparation is an important aspect for science education reformation. Bybee (1993) stated that changes of teachers empowerment are another aspect to keep the reform prevail.

Teacher Readiness to Reformation

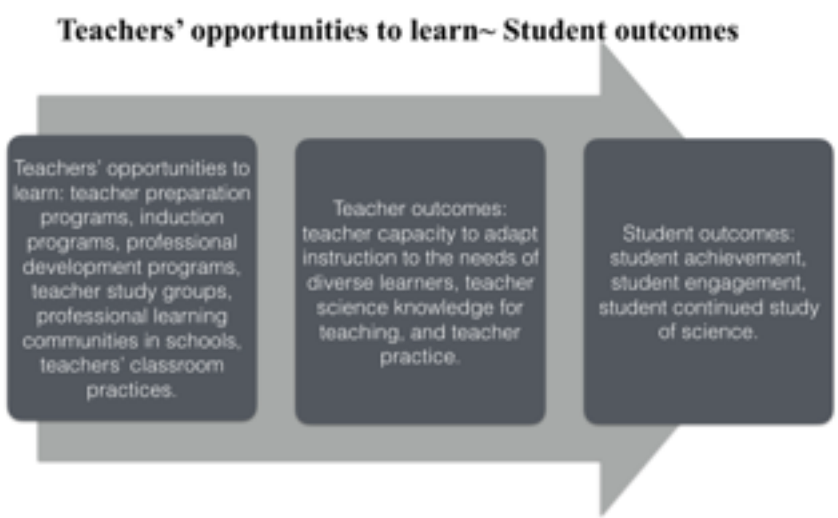
Teacher preparation for reformation is the primary step to bring reform into the classrooms. There are some school science programs and strategies can be used to achieve reform among the teachers. In this study participants reported that they do not have adequate knowledge and understanding about the new perceptions such as inquiry and STEM. However, they reported that they understand what does mean by STEM, or they are integrating science with other disciplines such as engineering, technology or mathematics to bring STEM into their classrooms. Additionally, the participants also reported that existing science curriculum, professional development or instructional material is not good enough for practicing STEM-based science education in Bangladesh. In this circumstance, teacher preparation will be the most significant challenge for reformation in Bangladesh.

Council (2016) stated teachers' learning as a dynamic process. There are few teacher professional development process such as initial preparation, early-career program, formal professional development to prepare science teacher for implementing new perceptions in the classrooms as well as make the reformation happen (Council, 2016). Council (2016) recommended both essential contents for science teacher preparation and types of programs based on their opportunity to learn.

Teacher Professional Development Programs

Professional development programs are the opportunities for teachers to know essentials to achieve student outcome (Council, 2016). There is some teacher learning experiences or purposes of the professional development programs: (1) intended kind of teacher changes, (2) duration of engagement outside classroom or school, (3) total duration of a school year, (4) follow-up activity over the school (Council, 2016). The newly designed STEM education professional development will follow this basic principle to bring STEM into the classrooms. He also recommended a flowchart from teachers opportunities to learn to achieve expected students outcome through a teacher preparation program.

Figure: 5.2 Linking teachers learning opportunities to teacher learning to student learning



Teachers Learning Outcomes

The flowchart (figure 5.2) recommended understanding scientific ideas and concepts as well as practice in a new situation. Therefore, teachers and educators' preparation programs should be an emphasis on different disciplines on implementing successful STEM education. Council (2016) recommended for three domains for teachers outcomes: (a) teacher capacity based on learners diversity, (b) content Knowledge, (c) Pedagogical Content Knowledge, for successful teacher preparation programs.

(a) Teachers position based on learners diversity

Council (2016) stated that to replace traditional memorization based science education into inquiry-based STEM education is a big challenge for the students. He added that intellectual and learning science in the second language could be more challenging for students diversity—language, culture, race, ethnicity, socioeconomic status, and new curriculum expectations. Therefore, teachers need necessary preparation, training, and skills to deal with diversity and bring changes in classrooms. Diverse professional development programs can help the teachers to enhance their essential quality to bring changes among the students.

(b) Content Knowledge

STEM-based science education focuses on four disciplines—science, technology, engineering and mathematics (NRC, 2012; NRC, 2014). STEM education has considered as an integration of at least two or more of these four disciplines. This study found that teachers have certain knowledge on individual STEM subject. However, STEM education requires integration based on the nature and practice of the disciplines and requirements. Therefore, professional development consist on STEM-based four content knowledge and integration will be a major challenge to prepare STEM-based curriculum for the teachers, development of instructions and classroom practices for Bangladesh.

(c) Pedagogical Content Knowledge

Shulman (1986) introduced pedagogical content knowledge (PCK) enhanced science education to improve teacher education programs through effective teacher learning. He mentioned that PCK is a tacit or hidden knowledge to help teacher in the science teaching-learning process. Shulman also statement PCK as a useful tool for the novice teacher to become an expert for designing effective science teaching pedagogy. Council (2016) stated that PCK emphasis on three different area of knowledge: knowledge of content and students, understanding of content and instruction, and knowledge of content and curriculum. Knowledge of content and students in the instruction help teachers to design and practice effective teaching-learning. On the other hand, knowledge of content and instruction outlines the strengths and limitations of an individual instructional strategy. Another criterion of PCK is knowledge of content and curriculum that describe the teachers choice to select any instructional materials that can or can not use based on the curriculum (Council, 2016).

Features of Effective Professional Development Programs

Since we have discussed the importance of science education reformation, effective professional development programs are also essential for reform. Eisenhower professional development program has introduced both core and structural features of an effective professional development (Council, 2016). This professional development program mentioned three set of core features and three structural features of a professional development program. The core features are: (1) focus on content (e.g. science and mathematics), (2) opportunities to learn, (3) coherence with other professional learning activities; and the structural features are: (1) the form of activity (workshop or study group), (2) collective participation (from same school, same grade, or same subject), (3) the duration of the activity. Bangladesh needs necessary reformation on teacher preparation programs following these criteria to implement successful STEM education.

Intended Impact of Professional Development Programs

Professional development programs impact is one of the major considerations of reformation process. Council (2016) recommended three types of intended results: (1) changes in teachers' knowledge and beliefs, (2) changes in instructional practice, (3) changes in students outcomes, from the professional development programs based on the logic model (figure: 5.1).

Changes in Teachers' Knowledge and Beliefs

This study explored science teachers' knowledge and beliefs on inquiry and STEM education reported by the participants. The participants reported that they know, understand, and practice some level of inquiry and STEM education. However, the participants also stated that they do not have adequate training on inquiry and STEM that can transform their knowledge and beliefs. Council (2016) reviewed some research on teachers knowledge and beliefs. The review found that teachers responded on following concepts for professional development— inquiry or process skills focused professional development, disciplinary content knowledge, pedagogical content knowledge, pedagogical content knowledge for argumentation, pedagogical content knowledge related to scientific argumentation, knowledge of students conceptions of argumentation, knowledge of instructional strategies for argumentation. Therefore, to make a successful reformation changing teacher knowledge and beliefs are important.

Changes in Instructional Practice

Instructional practice is another indicators of the reformation. This study explored teachers current instructional practices in science classrooms too. Council (2016) stated few research reports on instructional practice shift through new professional development programs. The reports found that newly hired teachers had a better impact on instructional practice. Another report found that teachers' attitude significantly changed both in content knowledge and pedagogical content knowledge. Other researchers enhanced amount of instructional time, curriculum materials instructional planning and practices are also essential for improving instructional practice. Therefore, Bangladesh needs a necessary transformation in teachers instructional practices to make the professional development more effected.

Changes in Student Outcomes

Council (2016) mentioned that students outcome gradually shift over time. Research found a positive correlation between students outcome and efficient, professional development. In other words, professional development helps teachers to sustain the knew knowledge and help the student to learn new perceptions and keep reformation real. Another research (2015) found that multiple years long professional development has more effect on students outcome than a short-time based professional development. Therefore, professional development might be designed based on expected student outcomes. So, both short-term and long-term based professional development will help to to achieve reformation goals.

Professional development based on diversity and second language acquisition has also found effective (NRC, 2015). Those research included inquiry-based learning in their professional development found effective for similar types of learning for students. Another study has made the comparison between literacy-embedded and inquiry-based science professional development and student outcomes. The study found significant improvement in inquiry-based science learning than literacy-based.

Teacher Preparation Program

Science education in Bangladesh needs a quality science teacher preparation program to make the 21st century science education shift. In ‘science teachers’ learning’, the scholars recommended fundamental changes in science being taught (NRC, 2015). It also recommended that teachers should know and practices new knowledge of ideas and practice of the disciplines and understand instructional strategies that new science education reformation envisioned. Therefore, it pointed out that teachers need profound support for learning the reform across their professional career through induction and professional development. Both in-service and pre-service teacher education program can be utilized to improve science education. However,

STEM-based Teacher Development Program

Tapan has reported (2010) inquiry-based science education in the 1970s aborted for lack of teacher preparation, instructional resources, appropriate inquiry-based assessment system, and parents cooperation. On the other hand, current laboratory-based science has not able to achieved for lack of successful implementation of laboratory uses. However, science education policy and curriculum concentrated on hands-on based science education, and it has been failed to build a competent teaching force. Regarding STEM, it is not only a conceptual shift across the field of science education but also instructional and learning shift based on multiple disciplines. Therefore, professional development should be an unprecedented effort to overcome all previous challenges and current implementation requirements.

Instructional Material Repository Model

From previous curriculum implementation failure, we found that science curriculum success highly depends on instructional materials availability and their utilizing ability. Since instructional material costs are one of the challenges for quality STEM education, the instructional repository can be set up for professional development from the beginning of the implementation. It will help to outline the education costs and necessary instructional design. It might help to develop professional development, research and enhance the teacher's performance as well as improve professional development program. In each repository, model should be based on 20-25 STEM teachers.

Figure: 5.3 Instructional Material Repository Model

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APPENDIX A

Survey Questionnaire

বাংলাদেশের প্রেক্ষাপটে বিজ্ঞান শিক্ষকদের বৈজ্ঞানিক অনুসন্ধান (Inquiry) ও বিজ্ঞান, গণিত, প্রযুক্তি, ও প্রকৌশল শিক্ষার (STEM Education) প্রস্তুতি যাচাই

Form ID No.	Grade Level: কোন কোন শ্রেণীতে বিজ্ঞান পড়িয়ে থাকেন ঃ
School Name: বিদ্যালয়ের নাম ঃ	Professional Role: Head Teacher/ Science Teacher/ Others পেশাগত পদবী ঃ প্রধান শিক্ষক/বিজ্ঞান শিক্ষক/ অন্যান্য
Medium: Bengali/ English কারিকুলাম ঃ বাংলা / ইংরেজি	Gender: F/ M পুরুষ / নারী
Age: বয়স ঃ	
By the end of the year, how many years will you have been teaching altogether? পেশাগত সময়কাল ঃ	How many months (in total) of **in-service teacher training** do you have? (Include projects/ training) মোট পেশাগত প্রশিক্ষণ সময়কাল ঃ
What is your current teaching position? (Circle your answer.) বর্তমান পেশাগত পদবিঃ i. Assistant Teacher ii. Junior Teacher iii. Senior Teacher iv. Assistant Head Teacher v. Head Teacher	What is the highest level of formal education you have completed? (সবশেষ অর্জিত ডিগ্রি) ঃ i. PhD ii. M.Phil iii. Masters iv. Bachelor (Hons) v. Bachelor (Pass/ 3yrs) vi. Others
Which of the following degrees describes your education? (নিচের কোন ডিগ্রী আপনি অর্জন করেছেন ?) i. Bachelor of Science (B.Sc.) ii. Bachelor of Social Science (BSS) iii. Bachelor of Arts (B.A.) iv. Bachelor in Education (B.Ed) iv. Others	What is your major area of study in your bachelor of science degree? (নিচের কোন বিষয়ে ডিগ্রী আপনি অর্জন করেছেন ?) i. Botany ii. Chemistry iii. Physics iv. Zoology v. B.Ed (Science Education) vi. Others
Do you have a master's degree? (আপনার মাস্টার্স ডিগ্রি আছে?) i. Yes ii. No	What is your major area of study in your Master's Degree? (মাস্টার্স ডিগ্রি থাকলে কোন বিষয়ে ?) i. Botany ii. Chemistry iii. Physics iv. Zoology v. M.Ed (Science Education) vi. Others vii. Not Applicable

How many years of pre-service teacher training (B.Ed) do you have? (Before starting your service or just after getting your job) আপনার কত বছরের প্রাক-প্রশিক্ষণ (B.Ed) আছে (শিক্ষকতা শুরু করার পূর্বে)? কত বছর পূর্বে প্রাক-প্রশিক্ষণ (B.Ed) করেছেন?	What are the subjects you are teaching right now? (You can choose more than one) আপনি এখন কোন কোন বিষয়ে পড়াচ্ছেন ? (এক- এর অধিক হতে পারে) i. Botany, ii. Zoology, iii. Environmental Science iv. Physics v. Chemistry vi. Math vii. Computer science vi. Others

পরবর্তী অংশের জন্য প্রযোজ্য

VSA= Very Strongly Agree = সম্পূর্ণ একমত (৬)

SA= Strongly Agree = আংশিক একমত (৫)

A= Agree = একমত (৪)

D= Disagree = একমত নই (৩)

SD= Strongly Disagree = আংশিক একমত নই (২)

VSD= Very Strongly Disagree = সম্পূর্ণ একমত নই (১)

14.	I encourage students to apply science and technology across disciplines. আমি শিক্ষার্থীদের বিজ্ঞান ও প্রযুক্তিগত জ্ঞান অন্য বিষয়ে (discipline) প্রয়োগ করতে উৎসাহ দিয়ে থাকি।						
15.	I encourage students to find STEM jobs. আমি শিক্ষার্থীদের বিজ্ঞান, গণিত, প্রযুক্তি, ও প্রকৌশল (STEM) পেশার জন্য উৎসাহ দিয়ে থাকি।						

দ্বিতীয় অংশ

Section Two:

বিজ্ঞান শিক্ষকদের শিখন-শেখানোর নির্দেশনা সম্পর্কিত তাত্ত্বিক ধারণা ও প্রয়োগ

Science Teachers Instructional Beliefs and Practices

		VSA (৬)	SA (৫)	A (৪)	D (৩)	SD (২)	VSD (১)
1.	I understand what is meant by "inquiry teaching". আমি বিজ্ঞান শিখন-শেখানোর ক্ষেত্রে বৈজ্ঞানিক অনুসন্ধান (Inquiry) পদ্ধতিটি বুঝি।						
2.	I often use inquiry in my teaching. আমি প্রায়ই বৈজ্ঞানিক অনুসন্ধান (Inquiry) পদ্ধতিতে বিজ্ঞান শিক্ষা দিয়ে থাকি।						
3.	I provide hands-on activities to help students understand scientific concepts. আমি হাতেকলমে (hands-on) কাজের মাধ্যমে বিজ্ঞানের বিষয়বস্তু পড়িয়ে থাকি।						
4.	I encourage the students to experience natural phenomena such as gravity, light, and magnetism. আমি শিক্ষার্থীদের বিজ্ঞান সম্পর্কিত প্রাকৃতিক ঘটনা বা বিষয়বস্তু যেমন- অভিকর্ষ, চম্বুকত্ব ইত্যাদির বাস্তব অভিজ্ঞতা (Experience) নিতে উৎসাহ দিয়ে থাকি।						
5.	I begin my lesson with probing questions focused on the lesson concept. আমি বিজ্ঞান পাঠের শুরুতে জিজ্ঞাসামূলক প্রশ্ন (probe questions) দিয়ে থাকি।						
6.	I give the opportunity to students to set up their own activities for exploring natural phenomena. প্রাকৃতিক ঘটনা (natural phenomena) সম্পর্কে জানতে আমি শিক্ষার্থীদের নিজস্ব অনুসন্ধান কার্যাবলী নির্বাচনে সুযোগ দিয়ে থাকি।						
7.	I use technology such as computers, PowerPoint software, tablets, the internet, or videos to enhance student learning. আমি বিজ্ঞান ক্লাসে প্রায়ই প্রযুক্তির ব্যবহার করে থাকি। যেমন - কম্পিউটার, পাওয়ার পয়েন্ট (Powerpoint), ট্যাবলেট, ইন্টারনেট, ভিডিও ইত্যাদি ব্যবহার করে থাকি।						

19.	I think in-service training would help me implement inquiry in the classrooms. আমি মনে করি চাকরিকালীন প্রশিক্ষণ আমাকে বৈজ্ঞানিক অনুসন্ধান (Inquiry) পদ্ধতি শ্রেণীকক্ষে প্রয়োগে সাহায্য করে।						
20.	I think my present curriculum is good enough to help me to use inquiry in my teaching. আমি মনে করি বর্তমান শিক্ষাক্রমের মাধ্যমে বৈজ্ঞানিক অনুসন্ধান (Inquiry) পদ্ধতি প্রয়োগ করার যথেষ্ট সুযোগ আছে।						
21.	I think schools have enough equipment and required facilities to practice inquiry in teaching. আমি মনে করি বৈজ্ঞানিক অনুসন্ধান (Inquiry) পদ্ধতিতে বিজ্ঞান শিখানোর জন্য প্রয়োজনীয় উপকরণ ও যন্ত্রপাতি বিদ্যালয়ে আছে ।						
22.	Administrators can help teachers begin to practice new science methods such as inquiry in classrooms. আমি মনে করি বিদ্যালয় প্রশাসন নতুন বৈজ্ঞানিক অনুসন্ধান (Inquiry) পদ্ধতি বাস্তবায়নে সহায়তা করতে পারে ।						
23.	I know about the learning cycle as a way of teaching inquiry science. আমি বৈজ্ঞানিক অনুসন্ধান (Inquiry) পদ্ধতিতে বিজ্ঞান পড়ানোর জন্য শিখন চক্র (learning cycle) ব্যবহার করে থাকি ।						
24.	I think that memorization is the most important in learning science/ STEM. আমি মনে করি বিজ্ঞান শিখার জন্য মুখস্থ (memorization) করতে পারা সবচেয়ে গুরুত্বপূর্ণ ।						
25.	I think teacher is generally responsible for students' learning in science. আমি মনে করি শিক্ষার্থীদের বিজ্ঞান শেখার জন্য শিক্ষকরাই সাধারণত দায়িত্বশীল ।						
26.	I think students' learning in science is directly related to their teacher's effectiveness in science teaching. আমি মনে করি শিক্ষার্থীদের বিজ্ঞান শেখা শিক্ষকের বিজ্ঞান পড়ানোর দক্ষতার উপর সরাসরি নির্ভর করে ।						
27.	I often encourage students more group work than individual. আমি শিক্ষার্থীদের দলগত অংশগ্রহণ ব্যক্তিগত কাজের চেয়ে প্রাধান্য দিয়ে থাকি ।						

তৃতীয় অংশ

বিজ্ঞান, গণিত, প্রযুক্তি, ও প্রকৌশল শিক্ষা (STEM Education)

Science, Technology, Engineering and Mathematics Education (STEM Education)

		VSA (৬)	SA (৫)	A (৪)	D (৩)	SD (২)	VSD (১)
1.	I understand what is meant by "STEM" আমি "STEM" মানে কি তা বুঝি।						
2.	I try to integrate engineering with science in lessons. আমি আমার বিজ্ঞান পাঠে বিজ্ঞানের সাথে প্রকৌশল (Engineering) ধারণার সমন্বয় (Integrate) করে থাকি।						
3.	I try to integrate mathematics with science in lessons. আমি বিজ্ঞান পড়ানের সময় গণিতের (Mathematics) ধারণার সমন্বয় (Integrate) করে থাকি।						
4.	I try to integrate technology with science in lessons. আমি বিজ্ঞান পড়ানের সময় প্রযুক্তির (Technology) ধারণার সমন্বয় (Integrate) করে থাকি।						
5.	I try to teach science and integrate at least two other of the following disciplines- engineering, technology or mathematics. আমি বিজ্ঞান পড়ানোর সময় বিজ্ঞানের সাথে গণিত, প্রযুক্তি বা প্রকৌশল এই তিনটির যে কোন দুইটি বিষয়ের সমন্বয় (Integrate) করে থাকি।						
6.	I have received training to help me integrate science, technology, engineering and mathematics. বিজ্ঞানের সাথে কিভাবে একাধিক বিষয়ের (গণিত, প্রযুক্তি ,প্রকৌশল) সমন্বয় করিয়ে পড়ানো যায় এ বিষয়ে আমার প্রয়োজনীয় প্রশিক্ষণ আছে।						

7.	I have engineering and technology lab equipment in my science lab and/or classroom. আমাদের বিদ্যালয়ে (শ্রেণীকক্ষ/ বিজ্ঞানাগার) প্রযুক্তি ও প্রকৌশল পড়ানোর জন্য প্রয়োজনীয় উপকরণ ও যন্ত্রপাতি আছে।						
8.	I often provide opportunities to develop a science or engineering project. আমি প্রায়ই বিজ্ঞান (Science) বা প্রকৌশল (Engineering) বিষয়ে প্রোজেক্ট ভিত্তিক কাজ দিয়ে থাকি।						
9.	I have been trained in how to change my classroom to a STEM classroom. বিজ্ঞান পাঠসমূহে কিভাবে গণিত, প্রযুক্তি, ও প্রকৌশলের সমন্বয় করে নতুন পাঠ তৈরি করা যায় সে সম্পর্কে আমার প্রয়োজনীয় প্রশিক্ষণ আছে।						
10.	I think current in-service training is good enough to help teachers implement STEM in classrooms. আমি মনে করি বর্তমান চাকরিকালীন বিজ্ঞান বিষয়ক প্রশিক্ষণ বিজ্ঞান, গণিত, প্রযুক্তি, ও প্রকৌশল শিক্ষা (STEM Education) বাস্তবায়নের জন্য যথেষ্ট।						
11.	I think the present curriculum is good enough to permit teachers to use STEM in classrooms. আমি মনে করি বর্তমান বিজ্ঞান শিক্ষাক্রম বিজ্ঞান, গণিত, প্রযুক্তি, ও প্রকৌশল শিক্ষা (STEM Education) বাস্তবায়নের জন্য যথেষ্ট।						
12.	I often do STEM activities with my students. আমি আমার শ্রেণী কক্ষে বিজ্ঞান, গণিত, প্রযুক্তি, ও প্রকৌশল (STEM) বিষয়ক কাজ দিয়ে থাকি।						
13.	I teach using problem solving and critical thinking. আমি শ্রেণীকক্ষে সমস্যা-সমাধান (Problem Solving) ভিত্তিক ও যৌক্তিক চিন্তা (Critical Thinking) ভিত্তিক পাঠ দিয়ে থাকি।						

APPENDIX B

Government Permission Letter

গণপ্রজাতন্ত্রী বাংলাদেশ সরকার
মাধ্যমিক ও উচ্চ শিক্ষা অধিদপ্তর
বাংলাদেশ, ঢাকা।
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স্মারক নং- ৩৭.০২.০০০০.১১০.১৮.৯২.১৫.৭৮২ তারিখ ঃ ০২/০৮/২০১৫ খ্রি.

বিষয় ঃ PhD গবেষণার কাজে ব্যবহারের নিমিত্তে তথ্য সংগ্রহের অনুমতি প্রদান সংক্রান্ত।

উপর্যুক্ত বিষয়ের প্রেক্ষিতে জানানো যাচ্ছে যে, জনাব কাজী কে শহীদুল্লাহ Doctoral Candidate & Graduate Teaching Assistant হিসেবে College of Education, University of Nevada, USA-কে তাঁর আবেদনের প্রেক্ষিতে ঢাকা মহানগরীর তালিকাভুক্ত স্কুলসমূহ (প্রদত্ত তালিকা অনুযায়ী) থেকে উপাত্ত (ডাটা) সংগ্রহের নিমিত্তে যথাযথ সহযোগিতা করার জন্য নির্দেশক্রমে অনুরোধ করা হলো।

02.08.2015
(মোঃ হেমায়েত উদ্দিন হাওলাদার)
সহকারী পরিচালক (প্রশিক্ষণ-২)
ফোন: ৯৫৮৬৫৮৪

স্মারক নং- ৩৭.০২.০০০০.১১০.১৮.৯২.১৫.৭৮২(৮) তারিখ ঃ ০২/০৮/২০১৫ খ্রি.

সদয় অবগতি ও প্রয়োজনীয় কার্যার্থে অনুলিপি প্রেরণ করা হ'ল:

০১. পরিচালক (ক: ও প্র:/মাধ্যমিক), মাধ্যমিক ও উচ্চ শিক্ষা অধিদপ্তর, বাংলাদেশ, ঢাকা।
০২. উপ-পরিচালক (মাধ্যমিক), মাধ্যমিক ও উচ্চ শিক্ষা অধিদপ্তর, বাংলাদেশ, ঢাকা।
০৩. উপ-পরিচালক, মাধ্যমিক ও উচ্চ শিক্ষা, ঢাকা অঞ্চল, ঢাকা।
০৪. প্রধান শিক্ষক, ...।
(সংযুক্ত তালিকায় বর্ণিত স্কুলসমূহকে যথাযথ সহযোগীতার অনুরোধ সহ)
০৫. জেলা শিক্ষা অফিসার, ঢাকা।
০৬. জনাব মোঃ ....।
০৭. পিএস টু মহাপরিচালক(মহোদয়ের সদয় অবগতির জন্য), মাধ্যমিক ও উচ্চ শিক্ষা অধিদপ্তর, ঢাকা।
০৮. সংরক্ষণ নথি।

বিদ্যালয়ের নাম সমূহ

১। উদয়ন বিদ্যালয়
২। ইউ ল্যাব স্কুল
৩। নীলখেত হাই স্কুল
৪। আজিমপুর গার্লস
৫। অগ্রণী গার্লস গার্লস স্কুল এন্ড কলেজ
৬। ইঞ্জিনিয়ারিং গার্লস স্কুল
৭। বীরশ্রেষ্ঠ নূর মুহাম্মদ রাইফেলস স্কুল এন্ড কলেজ
৮। বীরশ্রেষ্ঠ মুন্সি আব্দুর রউফ রাইফেলস স্কুল এন্ড কলেজ
৯। বি এ এফ শাহীন স্কুল এন্ড কলেজ
১০। শহীদ আনোয়ার গার্লস স্কুল এন্ড কলেজ
১১। হারমেন মাইনার স্কুল এন্ড কলেজ
১২। হলিক্রস স্কুল এন্ড কলেজ
১৩। সিদ্দেশরী গার্লস স্কুল এন্ড কলেজ
১৪। ভিকারুন্নিসা স্কুল এন্ড কলেজ
১৫। মনিপুর স্কুল এন্ড কলেজ
১৬। মতিঝিল মডেল স্কুল এন্ড কলেজ
১৭। আইডিয়াল স্কুল এন্ড কলেজ
১৮। আদমজী ক্যান্টনমেন্ট স্কুল এন্ড কলেজ
১৯। ইঞ্জিনিয়ারিং গার্লস স্কুল
২০। ইঞ্জিনিয়ারিং স্কুল
২১। ফরিদ্দিন স্কুল
২২। ওয়েস্টইনড স্কুল
২৩। কাম্রিয়ান স্কুল এন্ড কলেজ
২৪। রাজউক স্কুল এন্ড কলেজ
২৫। গভঃ ল্যাব স্কুল
২৬। কাম্রিয়ান স্কুল এন্ড কলেজ
২৭। নিউ পল্টন স্কুল এন্ড কলেজ
২৮। সেন্ট্রাল গভঃ স্কুল এন্ড কলেজ
২৯। কুর্মিটোলা গার্লস স্কুল
৩০। রেসিডেন্টসিয়াল মডেল স্কুল & কলেজ
৩১। সৃষ্টি স্কুল এন্ড কলেজ
৩২। [illegible] স্কুল
৩৩।

০২.০৮.২০১৮

...Uddin Howlader (T3)
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