DEVELOPMENT OF SOL-GEL LABORATORY USING INQUIRY FOR HIGH SCHOOL STUDENTS

NAMGAY LHADEN

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.....
Miss Namgay Lhaden
Candidate

.....
Lect. Supan Yodyingyong,
Ph.D.(Science and Technology Education)
Major advisor

.....
Lect. Pirom Chenprakhon,
Ph.D. (Science and Technology Education)
Co-advisor

.....
Lect. Watcharee Ketpichainarong,
Ph.D. (Science and Technology Education)
Co-advisor

.....
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

.....
Lect. Namkang Sriwattanarothai,
Ph.D.(Science and Technology Education)
Program Director
Master of Science Program in
Science and Technology Education
Institute for Innovative Learning
Mahidol University

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was submitted to the Faculty of Graduate Studies, Mahidol University
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on
October 20, 2014

.....
Miss Namgay Lhaden
Candidate

.....
Ms. Usa Jeenjenkit,
Ph.D.(Science and Technology Education)
Chair

.....
Lect. Supan Yodyingyong,
Ph.D.(Science and Technology Education)
Member

.....
Lect. Pirom Chenprakhon,
Ph.D.(Science and Technology Education)
Member

.....
Lect. Watcharee Ketpichainarong,
Ph.D.(Science and Technology Education)
Member

.....
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

.....
Assoc.Prof.Wannapong Triampo,
Ph.D.(Physics)
Director
Institute for Innovative Learning
Mahidol University

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NAMGAY LHADEN 5536888 ILSE/M

M.Sc. (SCIENCE AND TECHNOLOGY EDUCATION)

THESIS ADVISORY COMMITTEE: SUPAN YODYINGYONG, Ph.D.,
PIROM CHENPRAKHON, Ph.D., WATCHAREE KETPICHAINARONG, Ph.D.

ABSTRACT

Students often find chemistry is a difficult subject andis not interesting due toits abstract nature and complex contents. The chemistry lessons in Bhutan are still taught through the traditional method, which is more focusedon rote learning. Students face difficulties in relating what they learn in the classroom to real worldsituation and daily activities.Rote learning demotivates students learning chemistry and thus students do not have a good attitude towards the subject.Therefore, this research study is aimed at developing aSol-Gel laboratory based on the inquiry learning approach for Bhutanese grade 10 students to help them gain more understanding, meaningful learning and a positive attitude when learning chemistry. The Sol-Gel laboratory, based on how to prepare silica gel,was developed using an inquiry learning approach. In this study, 64 students at grade 10 participated in inquiry learning using the Sol-Gel laboratory. The participants were selected by purposive sampling. This study investigated students' conceptual understanding, students' perception and preferences in the learning environment, towards the learning activity using conceptual tests, the CLES questionnaire and an interview. The conceptual tests, CLES questionnaire and interview were conducted prior and after the implementation of the Sol-Gel laboratory. The results showed that students had a positive attitude to learning as evident from the interviews and CLES questionnaire. The activities helped them gain more conceptual understanding and skills such as asking critical questions, predicting, solving problem, drawing inferences, communication, and etc. The inquiry activities provided the opportunity for students to interact verbally with other students to build scientific knowledge within the classroom. This Sol-Gel laboratory helped students to improve their understanding and attitudes towards important aspects of the laboratory including their eagerness to do the activities, their sense of value of the activity and the impact of the activities on their interest, enjoyment and understanding.

KEY WORDS: SOL-GEL/ SILICA GEL LABORATORY / INQUIRY LEARNING/ BHUTAN

83 pages

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Namgay Lhaden

CONTENTS (cont.)

CHAPTER I
INTRODUCTION

1.1 Overview

This chapter provides background and rationale of the study.The problem statement, research questions and significance of the studyare also mentioned in this chapter. This chapter also contains the definition of the important terms used in this study.

1.2 Background of the Study

Science is a systematic approach to understand natural world and how natural world works with testable explanations. It is done through observation of natural phenomena or through experimentation under controlled conditions. The word “science" maybe brings to mind with different pictures, e.g., a thick textbook, white lab coats and microscope, Einstein’s equations scribbled on a board, the launch of space shuttle, and so on. Though all of these imaginary images show some signs of science but none of them shows a full picture because science has so many facets.

Chemistry is one of the foundations of the subject in science. Improvements in chemistry concepts have been brought in the growing of modern economics.The improvements vary from the new way of synthesis materials or medicine to new understanding of some chemical reactions which make our life safer and easier. Chemistry studies about properties of the substances and changes they undergo. The range of study of chemistry extends from the focus in qualitative to quantitative. Learning chemistry means to understand the world around you.

Many studies have been done on the nature of the chemistry subject being abstract, highly conceptual, result oriented and students attitude towards studying chemistry proving the subject to be difficult (Taber, 2002; Stark & Gray, 1999;

Cheung, 2009; Yara, 2009; Adesoji, 2008). This abstract nature of chemistry along with other learning difficulties such as the mathematical expressions of chemical equations, demands high-level of thinking skill. Much can be done by rote learning and being able to recall in examination.Though students show some signs of learning in examination papers, researchers find misconceptionsand some basics of chemistry which are still not very clear at a degree level. Besides teaching,to inculcate positive attitude of the students towards learning science has been another task for the teachers. Attitude towards chemistry means interestsin studying chemistry and their attitude will be a catalyst to their learning. Unfortunately, researchers revealed that to a great extent of what goes on in science classrooms is not particularly attractive to students across all ages (Stark & Gray, 1999; Cheung, 2009). This problem is also faced in Bhutanese classroom (Sherab, 2009). The Bhutan board of examination show performance graph, negative in science and in particular for the chemistry subject. This is due to conceptually demanding nature of the subject and many other factors affecting the performances of learning chemistry. Teacher centered in teaching and learning is still more dominant in Bhutan (Sherab, 2009).The research conducted by Wangchuk (2011) on the factors affecting the learning of science in lower secondary school in Bhutan, identified that quality of teaching and students' attitude were the major factors resulting in poor performance in sciences by Bhutanese students.

Recently, the way or how to teach science to students has become an interest of many researchers. Because of the nature of scientific knowledge rapidly increase and radically changed overtime, so many countries in the world reforms the way to teach nature of science and scientific inquiry in science education (Osborne, et.al, 2003). Effective teaching can be possible when students are willing and the teachers make use of appropriate methods and resources (Dobbs,2008). According to The National Science Education Standards (National Research Council, 1996) many educators have used inquiry based model to deliver a richer learning for the learners.Modern science teaching and learning process stress on student's participation through exposure to diverse learning experiences (Flynn, 2012). There are many advantages of using inquiry based learning in science. National science education standard confirms the opinion that inquiry is central of the achievement of scientific literacy (Hofstein, 2004). Teaching must involve students in inquiry oriented

investigations in which they interact with their teachers and friends. Class discussion, collaborative projects and other active learning tasks are few of different approaches of inquiry based learning. This approach encourages students to think and question on the topic being learnt and its relation with other subjects. Higher level of knowledge and understanding can be attained through this mode of teaching (Jones, 2003).

The chemistry laboratory is a good resource for supporting inquiry learning environment. Students engage in problem solving, planning, decision making, group discussions and other activities in learning science through the experiment. The experiments help learners recollect their prior concepts, encourage them to know their personal talents, and understand the nature of science and scientific inquiry.

Therefore, in this research study, we developed sol-gel inquiry laboratory for grade ten students to enhance their conceptual understanding about the technique for preparing materials (sol-gel technique), inquiry skills and improve their attitude towards learning chemistry. The laboratory is about making silica gelfrom sodium silicate solution using sol-gel technique. This technique is a general method for preparation of materials in an industry. This inquiry laboratory will help them to see the real applications of what they lean and engage them in learning chemistry.

1.3 Problem Statement

Teachers–centered approaches have been still followed in teaching and learning in universities and schools around the world and same is followed in Bhutan (Dobbs, 2008; Sherab, 2009).The chemistry laboratory is usually done by following cookbook or manual or with lectures from teachers in Bhutan. Students follow the instruction given by the teacher to carry out the laboratory which provides no room for students to critically think and learn on their own. The traditional lecture based laboratory method fails to motivate students to learn more and fails to connect between the laboratory and key concepts and fails to relate to their life (Wangchuk, 2011).Since the inquiry learningapproach has been proved very effective in promoting students understanding of the contents and motivating the students to learn the subject

more. So,there is a need to develop an appropriate inquiry leaning forBhutanese students.

1.4 Research Questions

This research will address the following questions:

1) Does sol-gel laboratory using 5E inquiry approach help Bhutanese students understand the sol-gel concept?

2) What are Bhutanese high school students understanding of concept after having participating in the sol-gel laboratory using inquiry approach?

3) What is Bhutanese high school students' attitude towards the sol-gel laboratory using 5E inquiry learning?

1.5 Research Objectives

1. To develop sol-gel laboratory for enhancing students' understanding of the sol-gel concepts by using 5E inquiry learning approach.
2. To investigate Bhutanese high school students' conceptual understanding after intervention of the learning unit.
3. To investigate whether there is any change in these students' attitude towards learning after having participated in the sol-gel laboratory using 5E inquiry approach.

1.6 Significance of the Study

The significance of this study is that the sol-gel laboratory leaning used as intervention is based on 5E inquiry learning approach. The leaning activities will help engage students in learning chemistry; understand nature of science and scientific inquiry through the laboratory.The sol-gel technique was used to prepare silica gel from sodium silicate and nitric acid. Silica gel is the general chemical the student can

find in everyday life. Sodium silicate was selected in this laboratory because it is a common chemical, easily available at low cost. It can be also made from rice husk ash by react with sodium hydroxide, which is easily available. It is stable substance and safe for students to handle.Moreover sodium silicate is a substance which is found in many of the household items like detergents which are more familiar to the students. This is not only economical but also suitable to teach some concepts of chemistry. The learning process in this laboratory will be intended to encourage students to construct their knowledge by themselves. This study will also improve Bhutanese students understanding of inquiry learning and attitude towards learning chemistry.

1.7 Definition of Terms

Constructivism: is a theory of knowledge in which humans generates knowledge by their experiences and interactions with the learning environment. The theory of learning which focuses on acquiring knowledge by active construction (Fox, 2001) and the knowledge is constructed in the minds of the learners (Bodner et al., 2001).

Inquiry based learning: is a learning strategy that teacher use to make learning active and meaningful. It is a technique used by scientist to study natural world using evidence based on scientific research. This learning strategy makes learners to authentically investigate nature, ask questions and interpret result using evidences.

Sol-gel technique: is a process or technique to preparematerials. This technique is a bottom-up approach for preparation of nanomaterials. It is a general technique for mass production of materials in industries.The process start from solution to gel. The final products can be make as thin film, powders, fibers, aerogel, etc. It used in varieties of process to produce better and durable things in the industries and factories for our daily uses.

Bouncing ball:is the ball made out of sodium silicate solution and ethanol. It is the polymer of sodium silicate. The substance made by mixing sodium silicate and ethanol. It has the flexibility property of polymer. When water is squeezed out and made round and thrown on the ground it bounces.

1.8 Expected Outcome

1) The result of this research will be useful for science teachers in Bhutan to improve their performance in teaching science using inquiry learning.

2) This study will serve as a reference for other Bhutanese researchers to research in similar related field of studies.

CHAPTER II
LITERATURE REVIEW

2.1 Overview

This section of the study talks about the goals and expected outcome of science education in Bhutan followed by some scientific reviews about sol-gel and application of sol-gel process. Educational reviews are also discussed and attitude reviews are also included in this section of the study.

2.2 Goals and key Learning Out Comes of Science Education in Bhutan

Department of curriculum and research department (DRCD,2011)

2.2.1 Goals

1) To enable learners to acquire knowledge and understanding of the natural sciences at a level appropriate to their development stage

2) To develop and apply the skills of inquiry, investigation, problem solving and logical reasoning

3) As a result of goals 1 and 2, learners will be 'scientifically literate' will be able to participate in critical and informed on key questions and issues that may affect their own lives, their community and their country

4) To prepare learners for higher studies in science and technology

5) To equip learners with the knowledge, understanding and skills in science to allow them to make a smooth transition into jobs in the workplace that require an understanding of science

6) To instill in learners a love and care for the natural environment and to develop the necessary understanding to be able to live harmoniously with nature and realize the goal of sustainable development

7) To equip learners with the knowledge of local as well as global environmental and ecological problems, their consequences and solutions

8) To develop a sense of health and wellbeing and how to live a healthy life

9) For learners to understand that there are some questions science can address but there are others, for example questions of religion, that it cannot

10) To inculcate in learners a love of learning science and learning in general this will carry throughout their lives

2.2.2 Key Learning Outcomes

Learners should be able to:

1) understand scientific concepts and acquires skills for their level of learning and for their lives as citizen or as future science professionals

2) develop their skills of inquiry in order to carry out investigations and experiments

3) transfer the skills of inquiry to be active and critical citizens

4) develop the ability to use information critically from a wide range of sources to answer scientific questions, address misconceptions and issues in society and life

5) apply their knowledge and understanding of science to solve key problems and for the conservation of the environment including adopting the principles of reduce, reuse, recycle and refuse

6) develop their abilities for meeting the scientific and technological needs and aspirations of the country and day to day life

7) develop a sense of ethics and responsibility by understanding that the knowledge science has generated has been used by humans to cause harm as well as contributing positively human development

8) share the skills learnt in science with other citizens to develop effective communication in Bhutanese society

9) acquire qualities of commitment, self-confidence, curiosity, creativity, integrity and adaptability

10) develop a sense of honesty, a sense of the importance of their contribution to their family, community and country and understand the value of working together as a team

2.3 Scientific Review

2.3.1 Sol-Gel Process

Sol-gel process is a process of producing materials. It is the bottom up approach to synthesis nanomaterials. The method is widely used in production of series of silica gel, xerogel, aerogel, and others materials. The process uses low energy, solution process. So, it widely used in a real industrial production. The reaction starts from small particles. In the solution small particles react with other and form react bigger particles. These particles link with each other and form a continuous three dimensional solid networks throughout the liquid. The continuous three dimensional solid networks make the gel firm and stable like solid. The liquid inside the gel make the gel soft and weak. This process can be used to make powders, thin films, monoliths, and fibers.

2.3.2 Sol-gel Mechanism

The mechanism of sol-gel process usually consists of hydrolysis and condensation

Hydrolysis reaction is a chemical reaction of reactants with water, water as one of the reactants. The hydrolysis, in sol-gel process, generally occurs when an alkoxide react with water and by product is alcohols. The intermediate that exist as a result of partial hydrolysisisSi-OH group, called the silanol group. The complete hydrolysis would give thesilicic acid. General hydrolysis reaction of alkoxide with water is show below.

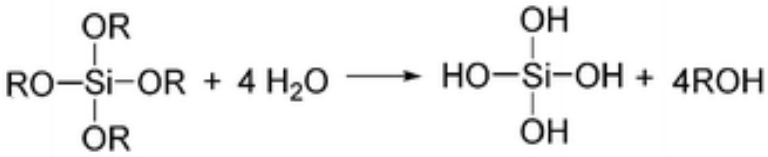


Figure 2.1 Hydrolysis Reaction of Alkoxide

Condensation reactionis reaction that molecules or small particles combine to form a larger molecule or larger particles and loss some small molecules or particles. In the sol-gel process for making silica gel, the small particles of silicon dioxide in the solution combine together to form bigger particles and have a chain link between particles which form a three dimensional of solid network thorough out the liquid. Water in the solution fills up the pores inside of the solid network which make the gel soft and jelly like substance. The process of linking small particles of silicon dioxide to form chain of network is known as condensation as show in figure 2.2.

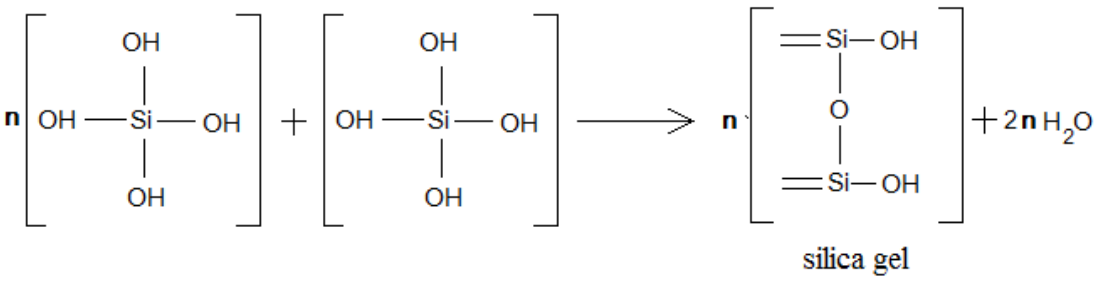


Figure 2.2 Condensation Reaction in Sol-Gel Process to form Silica Gel

The sol-gel process used in this research is the reaction of sodium silicate solution with nitric acid. The reaction is not the same as in the general sol-gel process. It is a type of acid-based reaction, reaction between sodium silicate and nitric acid. The formation of the gel starts from the neutralization reaction between sodium silicate and acid. When nitric acid is added to sodium silicate solution neutralization reaction take place. The particles of silicon dioxide in the sodium silicate solution become smaller particles. It has the hydroxyl groups on the surface which is the active

functional group. These functional group on the surface of particles of silicon dioxide will combine with each other to form a bigger particles of silicon dioxide and have the link to others particles. These links will form a continuous three dimensional network spreading thorough out the liquid which make the gel structure quite strong like solid.

When nitric acid is added to sodium silicate solution, the neutralization reaction takes place as in the reaction below

$$Na_2SiO_3 + HNO_3 \rightarrow \underset{(silicic\ acid)}{Si(OH)_4} + Sodium\ salt$$

The intermediate, silicic acid, will resulted in the condensation reaction and form the silica gel. The sol-gel process to for the reaction between sodium silicate solution and nitric acid is shown in figure 2.3

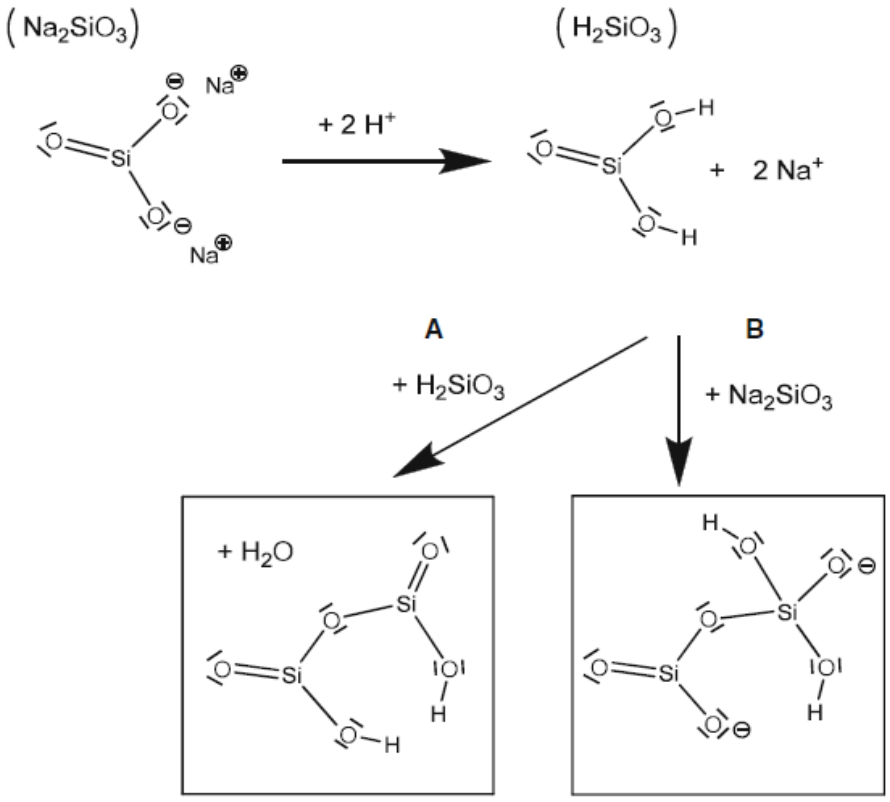


Figure 2.3 The Sol-Gel Process for Making Silica Gel from Sodium Silicate Solution and Nitric Acid (Michel et.al, 2011)

The factors affecting the sol-gel chemistry are concentration of the starting materials, pH, temperature, time, catalyst, stirring speed etc. In the learning activities, students studied the factors of concentration of sodium silicate solution and pH.

Concentration of sodium silicate solution - higher the concentration of sodium silicate solution the gel forms faster because it contains more silicon dioxide particles. When there are more silicon dioxide there is more chances of particles to collide with each other and link faster to form the gel.

pH of the solution during gel - Different concentration of solution forms gel at different pH. The pH effect the rate ofneutralization reaction and condensation reaction. The pH to form silica gel can in the range from pH 3 to 10.

2.3.3 Application of Sol-Gel Process

Sol-gel method is widely used in many fields depending on the requirement properties of materials. Because of the sol-gel is the solution process, use low energy, and can do in the big scale. So, this process is the general process for preparing materials in the industrials scale. The sol-gel derived products have lots of applications. It can be in form of powders, thin films, fibers, and monolith. Fibers can be drawn from the viscous of the sol-gel solution. The bulk materials can also be made by casting the gelling sol into mold. Coating film can be made by dipping the material in the sol solution (Sakka, 2005). Some of the important applications are; the application silica base materials as ink, coating for easy to clean, self-cleaning, anti-scratch, antifogging, anti-adhesive, and anti-corrosion(Ciriminna et al., 2012). In ceramic factory, the sol-gel technology is used to synthesize ceramics medium because it allows modifying the inorganic final properties on the account of its versatility, extending the range from organic to nano-fillers and also it allows obtaining highly reproducible nanoparticles with controlled size, structure, and composition and surface properties.

2.4 Educational Review

2.4.1 Constructivism

Constructivism is a theory of knowledge that humans construct knowledge by active learning of their experiences and their ideas instead of transferring knowledge (Duit and Treagist, 1995). Many educators and researcher accept constructivism as a viable theory of knowledge. This modern learning theory dates back to research done by John Dewey in 1933, by Jean Piaget in 1972, and by Lev Vygotsky in 1978. Vygotsky in Eastern Europe and Piaget in the Westhad huge impact on the schools of thoughts. The two main practices of constructivism are cognitive constructivism based on Piaget's cognitive development and social constructivism based on Vygotsky's social con text of leaning. The cognitive constructivism says that an individual must construct their own knowledge through their own experiences. It is the learning or understanding that happen within the learners based on their prior knowledge or experiences. Social constructivism focuses on social contexts that can help improve learning. These social contexts are cultural history, society, and language which are important to help improve learning of children. The characteristics of constructivist learning are active involvement of learners, inquiry learning, solving problem, collaboration and communication with peer or the teacher. The role of teacher is to guide, facilitate and co-explore. Social context such as more experienced peer can help a child master concept and ideas which they cannot understand on their own. The role of teacher is very vital as they interact, encourage and give feedback to students (Brynes, 1996).

2.4.2 Inquiry Based Learning

Inquiry based learning is a teaching strategy that can help students learn as the way scientist doing research. It can help students to improve to confront the real world with higher level of thinking, developed knowledge and practical skills by actively participating in learning. The interest, curiosity and perspective of students generate questions and learning takes place during the leaning. It is a method that encourages students to discover and construct knowledge and information by themselves (Huziak-Clark,T., et al, 2007). The teachers guides and encourages

students to construct knowledge by exploring the world around them (Santrock, 2001).Inquiry based learning and theoretical framework of inquiry based learning foundation is evident in early 1900s in the work of John Dewey. “The Child and the curriculum” a book by Dewey discuss about the need of reform from the traditional teaching and learning approaches that focused mainly on teachers presenting the curriculum without considering the needs of the child. An idea of more student centered and more meaningful learning has been discussed by Dewey. He characterizes need for constructivism by saying subject matter can never be understood unless learners are actively involved in learning activity. The active participation of students in the learning is required an inquiry based learning, a category of active learning (Biggs, 1999). Students participating in active learning environment learn much more than those participating in less active learning environment. In inquiry learning, students need to take active part in learning process.Many benefits of inquiry learning have been shown in research studies. Students have more control over learning process in gaining knowledge and have more opportunity to learn by doing in inquiry learning. Students gain knowledge in the process of learning not as a product at the end of the learning. In the learning process, students’ curiosities and motivations help students learn until they get the answer (Salvin, 2006). Learning has more meaning as students find relevance in what they learn to their real world lives (Acar &Tarhan, 2011, Ward, 2001). This type of learning environment promotes students’ curiosity and motivates them to investigate their interest and encourages independent learning. Students are not motivated just because they are actively involved but they are motivated with the expectation of the finding the answer by themselves.

2.4.3 5E Inquiry Learning

The 5E learning model was first used as three phase learning model which includes exploration, concept introduction, and concept application. In the first stage, students will explore in the activities and links previous experiences with present knowledge and see the relation. In the second stage teachers uses different media to introduce the concepts. And in the final stage, students lean to apply the knowledge to new situation. The 5E learning cycle includes the following phases: Engagement,

Exploration, Explanation, Elaboration and Evaluation (Bybee et al., 2006; Balci, et.al, 2006).

*Engagement***:** In this phase, the teacher generates students' curiosity to learn by creating interesting activities. The activities will help students to make connections of what they will learn with their experiences and knowledge.The teacher can use an activities or asking questions to prompt students to learn.

*Exploration***:** In this stage, students explore and carry out the activities.They get direct experience with the activity and its environment. The role of teachers is to guide and facilitate the students to do or explore in the activities. This is the phase where students work in group to test their prediction and ideas, build new knowledge, try different methods and skills and carry out discussion with the group.

*Explanation***:** During this phasethe students explain the concepts and knowledge in their own word from the observations they have made during the activities.

*Elaboration***:** During this phase students should apply the concept and build on or extend understanding and skills. Students apply the concept to another similar situation and make connection to their real live activity and make it meaningful.

Evaluation:In this stage, the knowledge, skills and abilities of the students are assed. The evaluation can takes place in all the phases of the activities. The activities had components to evaluate students' development in understanding and effectiveness of the lesson

2.5 Laboratory Work in Science Education

Laboratory work is an integral part of science teaching. The benefits of learning from laboratory work have a significant and distinct role in learning science. Science educators have shown benefits of learning from laboratory work. Following the procedure step by step instructions from the laboratory manuals is how usually students do laboratory activities. This style of doing laboratory does not provide opportunity for students to critically think and inquire. Many researchers have in

cooperated laboratory activities with other teaching methods such as inquiry based (Ketpichainarong et.al, 2010), problem based (Dobbs, 2008) and project based (Barak & Dori, 2005). The development of cognitive domain, development of affective domain and development of psychomotor domain are three categories benefits by doing laboratory using inquiry method (Ketpichainarong et.al, 2010).

2.6 Attitude

An attitude is an expression of feeling toward a person, place, thing, or even such aslearning activities. Students' attitude towards the learning is the result of learning experiences and its related activities which depends directly on the learning environment in the class. The attitude can effect students' achievement. If students have positive attitude towards the learning they will pay more attention on the learning which can results in better understating. When learner shows the expected behavior the effectiveness of learning also increases. The basic goal of teaching and learning science to get better performances from the students was to develop positive attitude towards learning science (Lavoie 1999). The achievement of learning depends on positive attitude which is influenced the learning environment or the leaning activities.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Overview

In this chapter, how this study is carried out, the research design, and methodology will be presented. The details of research design, participants, instruments, data collection and analysis will be discussed. The implementation of developed laboratory and the research frame work is also presented here.

3.2 Research Design

This one group pre-test and post-test research is used to study the effect of developed sol-gel laboratory without using control group.

Pretest ----------> Treatment ----------> Posttest

Through this study, the researcher intends to check students' attitude towards inquiry learning and students' conceptual understanding the concept of the sol-gel. The constructivist learning environment survey questionnaire (CLES) questionnaire and interview were conducted to find students attitude towards the learning environment and sol-gel conceptual test and open ended questions were conducted twice one before the intervention of sol-gel laboratory and once after the intervention.

3.3 Research Participants

There were 64 grade ten students from a school in Bhutan. The medium of language for teaching and learning is English. The English language is followed as

medium as prescribed by CAPSD. The students study general integrated science till grade eight and get introduced to chemistry in grade nine. This study was conducted at the end of academic session 2013. Therefore, the student would have studied chemistry for almost two years. The implementation of the learning activity was done by a volunteered teacher. The teacher was female of 34 years and have master's degree in natural science education and environmental and natural resources from university of Wyoming, Laramie, Wyoming, USA. She had been teaching chemistry and biology for grade ten for ten years.

3.4 Research Instruments

The measurement instruments used to collect data in this study were 1) the sol-gel conceptual test multiple choice, 2) open ended questions 3) CLES questionnaire (adapted from Taylor and Fraser (1991)) and 4) semi structured interview question.

Open ended and multiple choice sol-gel conceptual test was conducted twice once before the intervention of sol-gel laboratory to investigate how much students know about sol-gel process (pretest) and once after the intervention of sol-gel laboratory to investigate how much they have learnt after doing the laboratory (posttest). The questions were developed by the researcher based on the content of the laboratory and in line with the Bhutan curriculum.

CLES questionnaire was used to investigate students' attitude towards learning environment based on constructivist approach. This instrument has 20 items that have both positive and negative statements.

Semi structured interview questions were used to collect data of students' background and feedback of the implementation. The data from interview was used to support the CLES questionnaire for the exploration of attitude and opinions of the students regarding the implementation of developed sol-gel laboratory.

3.5 Development of Sol-GelLaboratory

The activities included in the developed laboratory were designed based on 5E inquiry leaning approach where students had to conduct their own knowledge reasonably by learning from their experiences. The steps for designing the laboratory unit are briefly summarized as follows:

The previous research works on developing learning units, inquiry laboratory and sol-gel processes were reviewed. Furthermore, the syllabus and objectives of Bhutanese curriculum of chemistry for grade ten were thoroughly reviewed and considered for development of sol-gel laboratory and lesson plan. A lesson plan of three hours was designed. Activities and details of laboratory are summarized in table 3.1. Refer lesson plan on appendix D

Table 3.1 Summary of Sol-Gel Laboratory

Phase	Activity	Objective	Time (minute)
Engagement	1) Students make a bouncing ball using sodium silicate and ethanol 2) Class discussion and students share their idea with their friends	1) Toengage students to the sol-gel concept by using a bouncing ball 2) Students lean the concept of condensation and polymer. These concepts will link to the concept of the reaction in the sol-gel reaction	15 minutes
Exploration	Students design and conduct their own investigation to make the silica gel by studying factors affecting the gel formation and time taken to form a gel	1) Students learn how to design and conduct an experiment 2) Identify the factors affecting gel formation and time taken to form a gel	60 minutes

Table 3.1 Summary of Sol-Gel Laboratory (cont.)

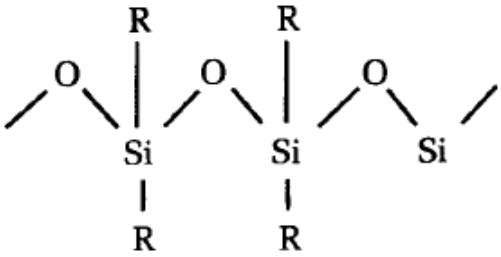
Phase	Activity	Objective	Time (minute)
Explanation	Students present their results and explain to the class	1) Understand the concept of sol-gel technique 2) Present the factors they find during the experiment	35 minutes
Elaboration	Students in group discuss, analyze and write their answers on the chart provide	Students understand the concept of sol gel and factors affecting the gel formation and applications of sol-gel process in others situation	50 minutes
Evaluation	Class discussion with guideline questions to check students understanding	To evaluate students understanding of the concepts and skills learnt during the lesson	20 minutes

The details of all activities, teaching steps and materials in each activity are described below.

Activity 1: Engagement (Making of bouncing ball)

In the beginning students were asked to define solid, liquid and physical changes and chemical changes to check on students' idea on changes of state of matter and concepts of physical and chemical changes. The teacher demonstrates how to make a bouncing ball using 10ml of ethyl alcohol and 40 ml of sodium silicate. Teacher measures 10ml of ethyl alcohol in a graduated cylinder and 40ml of sodium silicate in another graduated cylinder. Then mixes the two liquids and stirs for 1 minute. As soon as the two liquids are mixed the color changes and the states changes from liquid to solid. The teacher takes the solid in her hand and squeezes the water out and makes the solid in to ball shape and starts bouncing on the table. When ethyl

alcohol and sodium silicate are mixed the silicate particles begin to link with each other to form long chain (condensation reaction). Ethyl alcohol group replaces oxygen atom in silicate chains. The large molecule formed is solid and it is a type of silicone polymer. Figure 3.1 show the polymer from reaction of sodium silicate and ethyl alcohol. Students try to make the bouncing ball and bounce the ball and observe the properties of the bouncing ball. The students were asked to observe any changes and asked to discuss in their group about their prediction. The students wrote their observation on the paper and started to argue and discuss for their observation.



** R is the ethyl alcohol

Figure 3.1 The Polymer from Reaction of Sodium Silicate and Ethyl Alcoho**l**

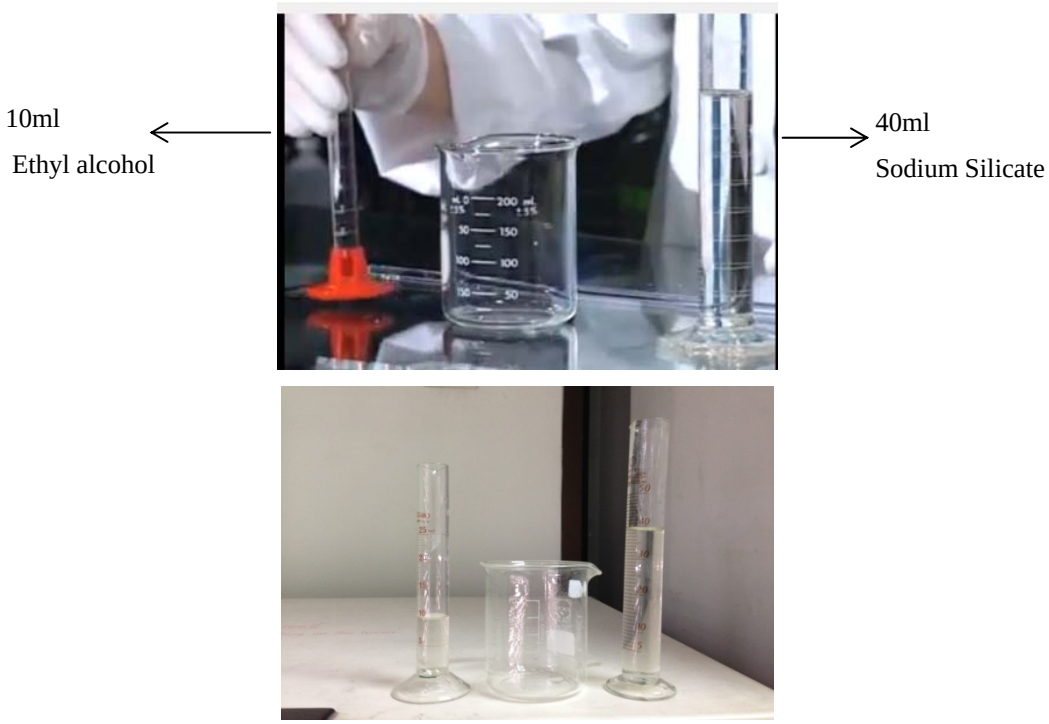


Figure 3.2 Teacher Demonstrating How to Prepare the Bouncing Ball

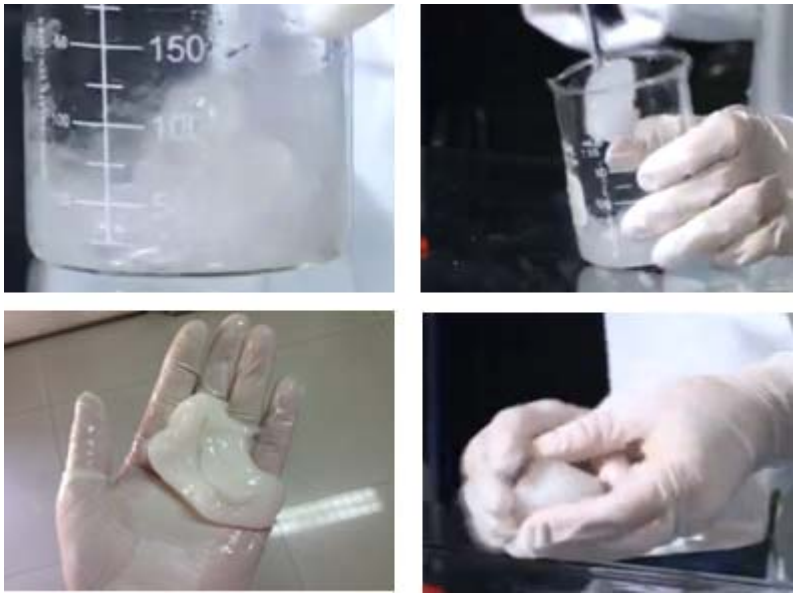


Figure 3.3 Formation of Bouncing Ball

Activity 2: Exploration

Firstly students were divided into groups of 5 to 6 members and were given the worksheet and materials to design their laboratory. During students design experiment, teacher checked in each group and guided students how to design the experiment. Then, students carry out the experiment and discuss the findings in their group and prepare to share with other groups. Students discuss about why different concentration of sodium silicate takes different time to from gel and have different color.

Activity 3: Explanation

Each group presented their results for the experiment, their observation and reasons to the class. While other students and teacher asked questions and made necessary comments. Teacher then provided each group a news print paper and asked them to write the answer of the following questions referring their observation table and discussing in the group.

1) How did the concentration of sodium silicate effect the gel formation?
2) Does pH have any affect one gel formation?
3) How can you increase the gel formation time?
4) Why is the solution clear in the beginning and visible after adding acid to it?

The students discussed the answer in the group and after all the students agreed to the common answer, they wrote on the paper to be presented to the class. Some volunteer students presented their answers to the class. Teacher gave necessary feedback on the discussion.

Activity 4: Elaboration

Teacher told students to be in the same group and again distributed chart papers and marker pens. And told them to discuss and write answer for the set of questions put on the chart. These were the questions:

1) What will be the structure of the gel? (Draw)
2) Where can this process be used?
3) What benefit we have from this process in our daily life?

4) Write some examples of sol-gel process?
5) What do you think about the edible jelly?

Students discussed in their groups debated and concluded with common answer for the questions. A few groups presented their findings. After and during the presentation whole class participated in the discussion. After all the groups agreed to one correct explanation, teacher added some more if need and confirmed the explanation.

Activity 5: Evaluation

Teacher evaluated students' understanding from students' answer and class discussion. After all the students agreed to correct explanation for all questions, the teacher recapitulated what the students have done so far and let few students talk about what they have learnt in this class, what they wanted to learn more and their feeling towards the developed laboratory. The students and teacher discussed thoroughly on what students thought in the beginning and what they have learnt. Like in the engagement part when teacher demonstrated how to make bouncing ball the students discussed and wrote why there is color change and why two liquids are mixed it changes to solid and so on. The lesson ended with students giving some example of application of sol-gel process in real life.

3.6 Data collection

3.6.1 Constructivist Learning Environment Questionnaires CLES

Constructivist learning environment questionnaires CLES was used to investigate students' attitude towards learning environment and towards learning chemistry. A set of CLES questionnaire were used to explore attitude towards learning chemistry before and after implementing the sol-gel laboratory using 5E inquiry. The CLES questionnaire was originally developed by Taylor and Fraser in 1991. Over the past few decades the CLES questionnaire has been accepted and expanded internationally and adapted and translated in many versions (Fraser, 2002). The CLES

questionnaire contains 6 scales and three items in four categories and four items in two categories each. The details of each scale used in this sol-gel laboratory are discussed.

Personal Relevance Scale (PR) scale is related to students' experience of school laboratory to their out of school lives. The scale is designed to measure to what extend students find relevance of doing laboratory their out of school live. According to constructivist point of view there should not be gap between what student do in the classroom and laboratory with their daily life activity. Instead laboratory environment for students to explore and engage students in experience the relevance of school science to their daily activities and use it.

Science uncertainty scale (SU) This scale is related to find how student knowledge can be applied in different ways in different situation and they also feel that scitntific theories are created by man and can be subjected to change over time depending on people's values and opinions.

Critical voice scale (CV) This scale is concerned with how students get more opportunities to question the teacher's pedagogical plans and voice their concerns and implements to their learning by inquiry learning approach as compared to their normal laboratory. As per constructivist perspective, the classroom should be focused on covering the curriculum content but teacher should show accountability to the class by nurturing critical attitude towards teaching and learning activities by creating social conducive environment.

Shared control scale (SC) This scale is concerned with students getting more shared control in inquiry laboratory than the normal laboratory. They have the opportunity to share control over the management of the learning activities and determination of the assessment criteria.

Student negotiation (SN) This scale is concerned with students having opportunities to explain and justify their ideas to other students and reflect on the viability of their own ideas.

Attitude scale (AT) This scale is concerned with students' preferences in the learning environment in this inquiry laboratory more than the normal laboratory class. Students feel the activities in the inquiry laboratory were interesting and make them understand more and more interested in chemistry. They should feel learning science in the inquiry laboratory make them enjoy.

The details of questions in each scale are shown below in table 3.2.

Table 3.2 Details of questions in each scale of CLES questionnaire

Scale	Questions
Personal relevance	1. New learning starts with problems about the world in relevance to my life. 2. What I learn in this class has no relationship to my life. 3.The concept learned in this class can help me to better understand the world in relevance to my life 20. I learn interesting things about the world related to my life.
Science uncertainty	4.I learn that the views of science can change over time 5. I learn that chemistry knowledge can be applied to be used in different ways. 6.I learn that science is influenced by peoples values and opinions
Critical voice	7.I feel free to express my opinion 8. I feel free to tell teacher about anything that stops me from learning 9. I can complain about the activities that are confusing.
Shared control	10. I help the teacher to plan what I am going to learn 11. I have a say in deciding the rules for classroom discussion. 12. I have a say in designing how much time I spend on an activity
Student negotiation	13. I get the chance to share ideas with other students. 14. I can talk with other students about how to solve the problem. 15. I ask other students to explain their ideas

Table 3.2 Details of questions in each scale of CLES questionnaire (cont.)

Scale	Questions
Attitude	16.I look forward to the learning activities
	17.The activities in this class makes me interested in science
	18. I am confused about the concept learned in this class
	19. The learning activities in this class are waste of time.

Adapted from Taylor and Fraser (1991)

Three open ended question were also given to get the in-depth understanding and students' attitude towards the developed sol-gel laboratory. The following were the open ended questions:

1) What did you learn overall from the activities in the learning unit?

2) What do you think you want to learn more from the activities in the learning unit?

3) Any comments or suggestions

3.6.2 Semi Structured Interviews

Semi structured interviews was conducted to gain insight into the student's perspectives and to check understanding of the lesson and attitude towards the learning activities. All dialogues during the interview were audiotaped. Few volunteer participants were interviewed twice that is before and after the implementation of sol-gel laboratory using 5E inquiry. The questions in the interviews were related to students attitude and understanding of the lesson.

Interview Questions

Content:

1) Explain your understanding about the neutralization reaction.
2) Explain your understanding about sol – gel process.
3) What are differences between solution, sol and gel?
4) Explain how to prepare a transparent silica gel

5) What are parameters that effect the gel formation?

Attitude:

1) Please tell me about yourself? Favorite subject and so on.
2) Tell me about the sol-gel laboratory that you learn in the class today.
3) In what way did you learn in the class?
4) Did this class stimulate your thinking skill? How?
5) Is the learning in this class different from other classes? How?
6) What challenges did you face from learning in this class?
7) Are the activities in this class interesting? How?
8) Does the teacher support you in learning? How?
9) Would you like to learn in this kind of class? Why?
10) Do you think the class can be improved? Why and How?
11) Did you know what was expected from you in the class? Please explain.
12) Overall tell me how did you feel about learning in this class?

3.6.3 Sol-Gel Laboratory Conceptual Test

The sol-gel conceptual test used to identify student's understanding of the concepts related to sol-gel Lab. The test compose of two part which is open-ended and multiple choice questions. The test was used to explore students' understanding before and after implementing the sol-gel laboratory using 5E inquiry. The test questions are list below:

Open-ended questions

1) Explain what are differences between gel, liquid and solid?
2) What is sol?
3) What are the mechanisms in the formation of sol-gel?
4) How does the concentration effect gel formation?
5) What are factors that affect the gel formation time? How?
6) Draw the gel structure and explain what you understand?

Multiple choice questions

1) Which of the following is not a polymer?

a) Silica

b) Silicone

c) Cellulose

d) Nylon

2) What is sol?

a) Sol is a solution.

b) Sol is solid.

c) Sol is a solid disperse in the solution.

d) Sol is sediment.

3) Which of the following is an example of sol?

a) Alcohol

b) Salt solution

c) Milk

d) Oil

4) What type of reaction occurs between sodium silicate and nitric acid?

a) Decomposition

b) Neutralization

c) Condensation

d) polymerization

5) Why is the solution transparent after adding acid to the solution?

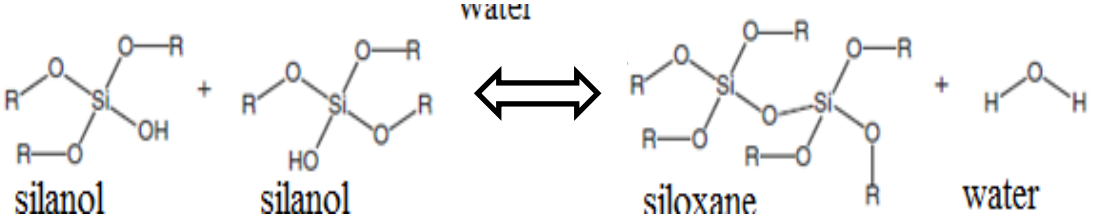
a) because the acid help to hydrolyze sodium silicate and make the particles in the solution become bigger

b) because the acid help to hydrolyze sodium silicate and make the particles in the solution become smaller

c) because the acid help sodium silicate to form a gel network

d) because the acid prevent sodium silicate to form a gel network

6) What type of reaction is occurring in the above reaction?



a) Hydrolysis

b) Condensation

c) Neutralization

d) Dissociations

7) What happens to gel formation as concentration of sodium silicate is changed

a) Concentration of sodium silicate solution not affect the gel formation.

b) The rate of gel formation decreases with increase in concentration of sodium silicate solution

c) The rate of gel formation increases with decrease in concentration of sodium silicate solution

d) The rate of gel formation increases with increase in concentration of sodium silicate solution

8) Which of the following is correct?

a) To forming a gel, it start from the silinols occur a hydrolysis reaction.

b) Sodium silicate solution can form gel at only a specific pH.

c) Silica gel is a continuous three dimensional network of nanoparticles spreading throughout the liquid

d) There is only solid inside silica gel.

9) Which of the following is not correct for the sol – gel process?

a) Sol –gel process is the top-down process for making nanomaterials

b) Sol – gel process is the bottom-up approach for making nanomaterials

c) Sol – gel process can use to make powders

d) Sol – gel process can use to make thin film

10) Which of the following are not the applications of sol-gel process.

a) To make an aerogel

b) To make fibers

c) To make porous materials

d) To make pure substances

3.7 Data Analysis

The data in this study was analyzed by both quantitative and qualitative analyses depending on data type.

3.7.1 Analysis of Constructivist Learning Environment Survey (CLES)

The raw datawas transformed into variables that were analyzed by SPSS 16.0 (statistical package for social sciences). Consistency of CLES questionnaire was investigated by Cronbach alpha reliability coefficient. The differences between pre-test and posttest were compared by using t-test.

3.7.2 Analysis of Semi Structured Interview

The interview data from the audio tape was transcribed they were analyzed using thematic approach to find how the sol-gel laboratory using inquiry was working on students' attitude. The findings were used to draw conclusions and used to support the CLES questionnaire and open ended sol-gel laboratory conceptual test.

3.7.3 Analysis of Sol-Gel Laboratory Conceptual Test

The researcher developed specific rubric for allocating 0-3 points for answers to each questions in accordance with the criteria for correctness. The total score was 3. The details of the scoring criteria are shown in appendix G**.** The ten multiple choice questions which had four options each correct answer was given 1 and

wrong answer is given 0. The data was analyzed by finding the percentage and of the students score in pretest and posttest.

3.8 Implementation of Developed Laboratory

Implementation of developed sol-gel laboratory to high school students and investigate the effectiveness of the laboratory to enhance students' understanding and promoting positive attitude towards learning. The summary of each stages are presented below

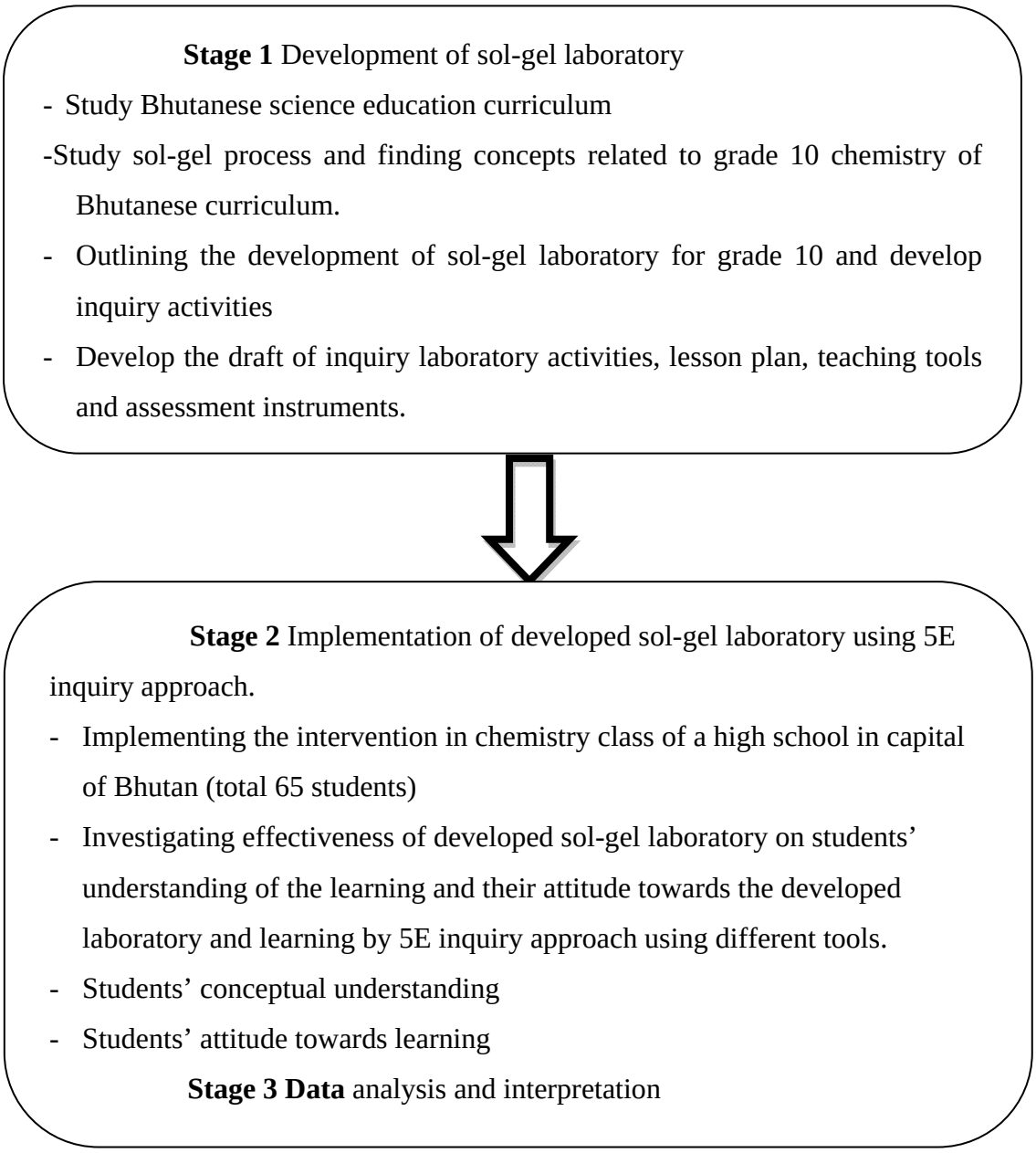


Figure 3.4 Summary of research methodology

3.9 Frame Work of the Study

The goals and expected outcome of science education in Bhutan is to develop and apply skills of inquiry investigation, problem solving, and logical

reasoning. To encourages students to develop their own scientific concepts for understanding and explaining natural phenomena.

It requires teachers to use active teaching and learning strategies for teaching to be meaningful for students to apply to their everyday life. The researcher developed the framework for this study as described below.

The fundamental theory was based on constructivism. The teaching and learning should focus on providing active learning environment, encourage students to construct new knowledge, stimulate thinking and social interaction. Individual actively participate with others in an attempt to understand and interpret for themselves and get stimulated to think in different prospective in social interaction (Diver et al., 1994).

Laboratory activities provided lots of options for students in learning science (Lawson, 2001). As explained above researcher planned to promote students understanding of concepts and improve students' attitude towards learning chemistry by applying inquiry learning approach. The sol-gel laboratory activity is developed based on 5e inquiry leaning because students were given opportunity to design experiments, collect data and analyze data. The students had time to share their ideas, conduct experimentand interpret result to the group members and to teacher.

CHAPTER IV
RESULTS

4.1 Overview

The main objective of this research study was to find the effects of inquiry method on the achievement of grade 10 students of Lungtenzampa Middle Secondary School, Thimphu, Bhutan in chemistry subject. This study is also intended to assess the students' opinions towards learning chemistry using the developedsol-gelinquiry laboratory.

In comparing and assessing the effects of laboratory using inquiry method on the achievement of grade 10 students in chemistry, the comparison between the pretest and posttest score was done by t-test with p-value at0.05 level of significance. In assessing the students' understanding and learning satisfaction level of students towards learning of chemistry using inquiry method, the data were collected fromopen-ended test, multiple choice questions, constructivist learning environment survey questionnaire (CLES) and semi-structure interview questions. The quantitative data were analyzed using descriptive statistics frequency, percentage, mean, and standard deviation.The qualitative data from semi-structured interview and questionnaires were code and count in term of frequency and percentage.

This chapter presents the key findings of the research study. 64 students took part in this study. All students were taught 3 hours laboratory using inquiry laboratory.

The results of data analysis are presented as follows:

4.2 Findings from the open-ended conceptual test

4.3 Finding form the multiple choice conceptual test

4.4 Finding from constructivist environment survey questionnaires (CLES)

4.5 Finding from semi-structured interview

4.2 Findings from the Open-EndedConceptual Test

The data revealed that all participants developed conceptual understanding of conceptand process. Regarding the concept test a t-test comparison of pretest and posttest of open ended conceptual test scores was done as shown intable 4.1

Table 4.1 Pretest and Posttest Scores from Open-ended Conceptual Test on Conceptual Understanding of Sol-Gel Concept (n=64, total score= 18)

	Pretest		**Posttest**		**Mean Difference**	**t-test**
	Mean	**SD**	**Mean**	**SD**		**T**
Conceptual Understanding	3.3	1.6	9.44	2.44	6.14	19.0

*significant difference at p =0.05

Students' open-ended conceptual test showed that students were able to understand the concept better after doing laboratory as evident from the results presented in table 4.1. The paired sample t-test to determine that there was a significant difference between the two mean score of the pretest and posttest.It wasapparent from the data analysis that there was increase in the achievement level of students at the end of the laboratory lesson.

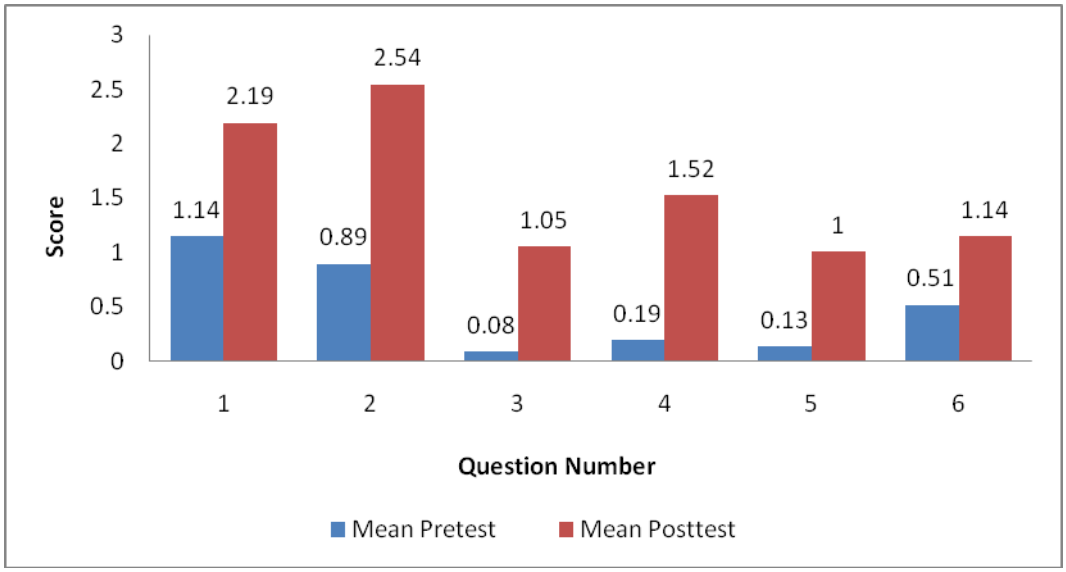


Figure 4.1 Mean of pretest and posttest scores of open-ended conceptual test

Figure 4.1 shows the mean of pretest and posttestscores of open-ended conceptual test. The results clearly show that there was an improvement of students' conceptual understanding after having participated in the learning activity.

4.3 Finding from the MultipleChoice Conceptual Test

Table 4.2 Mean of Pretest and Posttest, Mean Difference and Standard Deviation of Multiple Choice Questions

	Mean		Mean Difference	Standard deviation	
Question	**Pretest**	**Posttest**		**Pretest**	**Posttest**
1	0.22	0.59	0.37	0.42	0.5
2	0.59	0.97	0.38	0.5	0.18
3	0.06	0.73	0.67	0.25	0.45
4	0.41	0.79	0.38	0.5	0.41
5	0.22	0.6	0.38	0.42	0.49
6	0.16	0.48	0.32	0.37	0.5

Table 4.2 Mean of Pretest and Posttest, Mean Difference and Standard Deviation of Multiple Choice Questions (cont.)

	Mean		Mean Difference	Standard deviation	
Question	**Pretest**	**Posttest**		**Pretest**	**Posttest**
7	0.41	0.62	0.21	0.5	0.49
8	0.3	0.5	0.2	0.46	0.5
9	0.3	0.5	0.2	0.46	0.5
10	0.59	0.76	0.17	0.5	0.43
Total	**3.26**	**5.54**	**3.28**	**4.38**	**4.45**

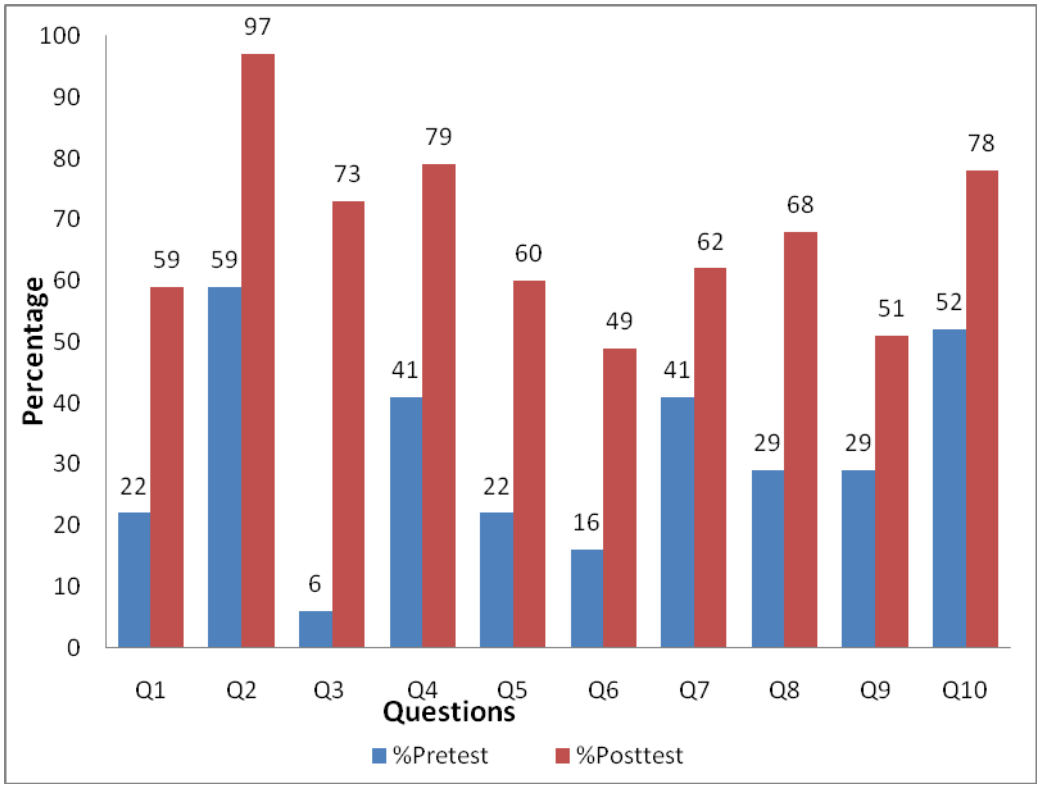


Figure 4.2 Percentage of Students' Score in Pretest and Posttest Multiple Choice Questions

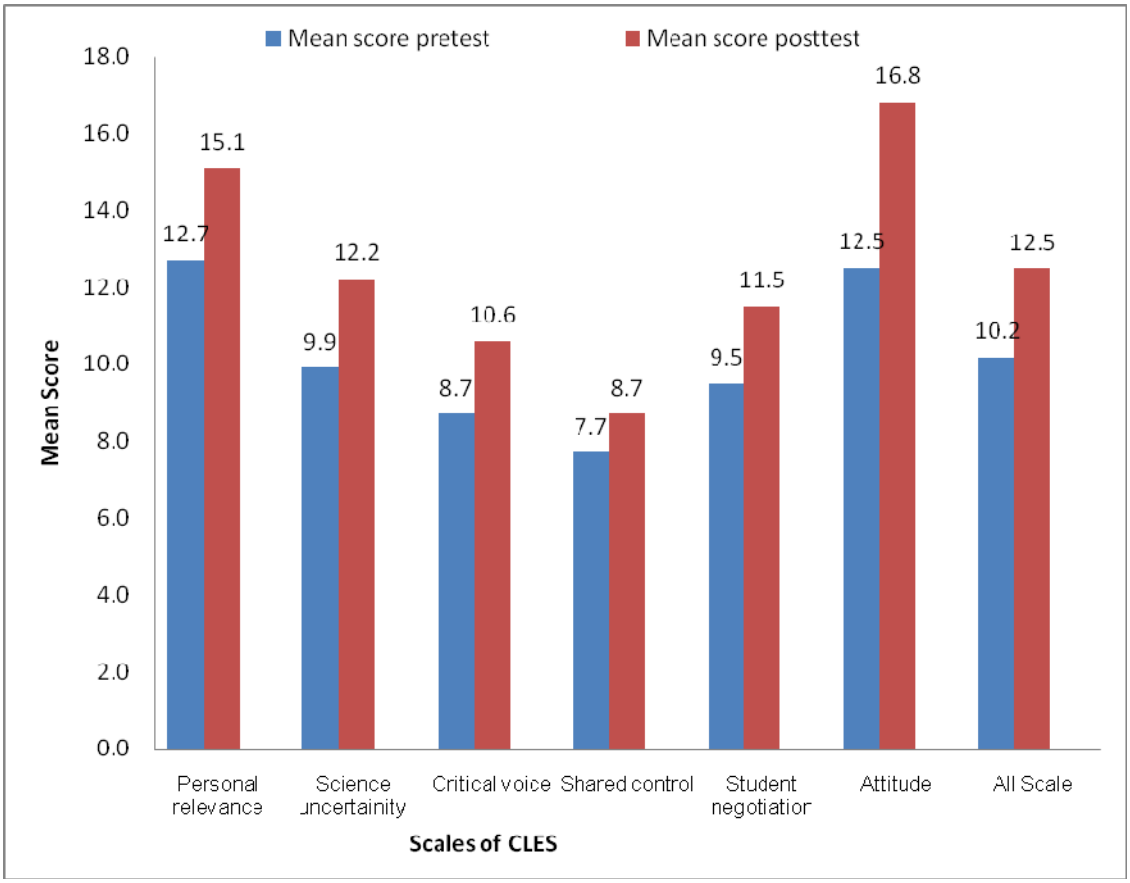
Table 4.2 shows mean of pretest and posttest, mean difference and standard deviation of multiple choice questions. The total scores of each question were converted into percentage for comparing pretest and posttest results as showed in

figure 4.2. The results from table 4.2 and figure 4.2 shows that the post test score from all the questions is higher than the pretest score. The improvement is highly significant in question number 3 which is about the concept of sol and example of sol. The mean difference of questions 1, 2, 4, and 8 are equally significant.These questions were about silica gel, examples of silica gel and sol, and the type of reaction between sodium silicate and nitric acid. In pretest the low percentage showed that the majority of the students had no idea about sol, and the type of reaction taking place during the formation of the silica gel. The significant increase in the score during the posttest shows that there was improvement of students understanding on concepts after taking part in laboratory. (Appendix A)

All the posttest scores are more than 50 percent except for question number 6 which is about the concept reaction occurring during the formation of silica gel.But when compared to the pretest (16 percent) it was much better in posttest (49 percent). The reason for students scoring low percentage could be because it is totally new concept for them and the concept is quite abstract for students

4.4 Finding from Constructivist Environment Survey Questionnaires (CLES)

Students' attitude towards developed using5E inquiry learning was investigated using constructivist learning environment survey (CLES). In the pre CLES questionnaire students were told to think about their normal traditional learning and in the post CLES questionnaire they were asked to answer regarding the developed inquiry laboratory. The overall post test scores were significantly higher than overall score of the pretest as determined by paired t-test. Significant difference was seen is each scale of the items. The result shows that the laboratory learning using inquiry learning helps improve students' attitude towards learning as evident form the result below. The mean pre and post- CLES are presented in figure 4.3



*significance difference at p =0.05

Figure 4.3 Mean Pretest and Posttest CLES Scores

The result in table 4.3 shows that the total means score of pre and post CLES questionnaire. All scales of the post CLES were significantly higher than those of pre-CLES questionnaires. The details of their response to each scale are described below.

Personal relevance

The mean score of student response on personal relevance before the intervention were 12.7 and after inquiry approach were 15.1.This difference shows that the inquiry approach class gave student more opportunities to perceive the relevance of school science and laboratory to their out of school live and to their daily activities and develop scientific knowledge meaningfully.

Scientific uncertainty

The mean score of student response on scientific uncertaintybefore the intervention were 9.9 and after inquiry approach were 12.2.This difference was sitisticallysignificant suggesting that inquiry laboratory gave students more oppurtunities to know that the knowledge can be applied in different ways in different situation and they also feel that scitntific theories are created by man and can be subjected to change over time depending on people's values and opinions.

Critical voice

The mean score of student response on critical voice before the intervention were 8.7 and after inquiry approach were 10.6. Students got more opportunities to question the teacher's pedagogical plans and voice their concerns and implements to their learning by inquiry learning approach as compared to their normal laboratory.

Shared control

The mean score of student response on shared control before the intervention were 7.7 and after inquiry approach were 8.7. This suggested that students got more shared control in inquiry laboratory than the normal laboratory. They had the opportunity to share control over the management of the learning activities and determination of the assessment criteria.

Student negotiation

The mean score of student response on student negotiation before the intervention were 9.5 and after inquiry approach were 11.5. These data shows that students had opportunities to explain and justify their ideas to other students and reflect on the viability of their own ideas.

Attitude

The mean score of student response on attitude before the intervention were 12.5 and after inquiry approach were 16.8.The students preferred the learning environment in this inquiry laboratory more than the normal laboratory class. Students felt the activities in the inquiry laboratory were interesting and made them understand more and more interested in chemistry. They felt learning science in the inquiry laboratory made them enjoy.

4.5 Finding fromSemi-Structured Interview

Ten volunteer students were interviewed individually for 10-15 minutes after they had participatedin theinquiry laboratory. The questions were asked to get their perception and attitude towards studying chemistry and their understanding of the concept on sol-gel. This gave further evidence to support the results that we got from the conceptual test open ended and multiple choice questions and CLES questionnaire. The detail information from the students' semi structured interview is presented in table 4.3. The frequency of students 'answer was converted to percentage to see the impact of developed sol-gel laboratory and attitude towards the developed sol-gel laboratory using inquiry. The frequencies for questions 1 to 4 werecounted once because one student gave only one answer. The questions 5 to 11, the number of frequency is more because some students gave more than one answers.

Table 4.3 Detail Information from Students' Semi-Structured Interview(n=10)

Interview questions	Frequency	Percentage
1. Understanding of neutralization reaction		
- The reaction between acid and base to from salt and water	7	70
- Acid and base combine to from salt and water	3	30
Reasons		
- Nullify each other as they have hydronium ion and hydroxide ion	6	60
- Form neutral substance water	4	40
2. Understanding of the sol-gel process		
- It's a process of forming gel	4	40
- It's a process in which small particles come together to form a continuous three dimensional network spreading thorough out the liquid	6	60

Table 4.3 Detail Information from the Students' Semi-Structured Interview (cont.)

	Interview questions	Frequency	Percentage
3	**Solution, Solid and Gel**		
-	Solid is state of matter that is firm and stable and liquid is also a state of matter but have no fixed shape and not stable. Gel is the material which has some properties like both solid and liquid.	6	60
-	Solution is mixture of solvent and solute, Sol is solid dispersed in liquid and gel is mixture of solid and liquid	3	30
-	Gel is a semi solid contains both solid particle and liquid particles	1	10
4	**Preparing transparent gel**		
-	Use 2% sodium silicate and 0.5 M nitric acid and maintain pH at 9 due to neutralization reactiona transparent gel is formed in around 18 minutes.	9	90
-	Using sodium silicate and nitric acid	1	10
5	**Parameters effecting gel formation**		
-	Concentration of acid	6	60
-	Concentration of sodium silicate	8	80
-	Stirring	8	80
-	Time	10	100
-	pH	7	70
6	**Opinion on learning science**		
-	Like	9	90
-	Neutral	1	10

Table 4.3 Detail Information from the Students' Semi-Structured Interview (cont.)

	Interview questions	Frequency	Percentage
7	**Opinion towards Laboratory**		
-	Fun	7	70
-	Interesting	7	70
-	Excited	6	6
Reason			
-	First time going to science laboratory	10	100
-	Got to do the experiment on our own and it is very new to us	10	100
-	Sol-gel was interesting topic	5	50
-	Learnt a lot	4	40
-	Working in group	8	80
8	**Thinking Skills**		
-	Yes	9	90
-	Neutral	1	10
Reason			
-	Because we had to do the experiment our selves	5	50
-	We had to think more because it was new and we had to do the activity our self	6	60
-	We had to see how the gel can be made	4	40

Table 4.3 Detail Information from the Students' Semi-Structured Interview (cont.)

	Interview questions	Frequency	Percentage
9	**Opinion towards the learning activities**		
-	Interesting	10	100
-	Fun	10	100
Reason			
-	The activities were interesting	8	80
-	We got to do our self	7	70
-	The discussion with friends was more interesting	6	60
-	Topic was interesting	5	50
-	Working with friends	7	70
-	Getting to handle laboratory equipment	6	60
-	I felt proud that we could get the result	1	10
10	**Opinion towards learning by inquiry**		
-	I would love to learn in this kind of way because we get to do our self and see	7	70
-	We get to discuss with friends and teacher	7	70
-	I feel we know more when we do activity	8	80
-	Discussion in the group and with teacher was enriching	7	70
11	**Suggestions and comments**		
-	Interesting	10	100
-	Had fun	7	70
-	Got some practical skills	5	50
-	Enriching and mind opening experience it broaden our perceptions	5	50
-	Should be bit more organized	1	10
-	Need more resources	2	20

From table 4.3,it is evident that students understood the concepts related to sol-gel process. 70 percent of the students could tell what neutralization reaction and

give reason.50 percent could explain the sol-gel process and remaining 50 percent could partially explain the sol-gel process even though it was totally new concept for them.

The results from tests CLES questionnaire and semi-structure interview show that developed sol-gel laboratory had positive impact on students understanding attitude towards the learning activity. They found the topic interesting and new. They got to do the laboratory by themselves, and they liked to discuss and share their ideas and listen to others friends' idea. Almost all the students said that the develop sol-gel laboratory made them think more as they had to explore and do the activities by themselves without much information from the teacher. They had to answer questions asked by their friends in group and reason out. Most of the students said they had to think more than the normal chemistry classes which they were had just to listen.

Examples of students' statements from the interview:

Some opinion of the students on laboratory quoted below:

"It was interesting because we got freedom to explore"

"Different from usual laboratory I was very excited to do it ourselves"

"Interesting we got to interact with friends and solve problems"

Questions regarding the laboratory activities

"It's different and more fun because we did not use laboratory manual, we discussed and very happy to know how we got the results"

"Got opportunity to go to school science laboratory"

Many students who are interviewed wanted to learn all science this way

"I wish we could do all science activity like this"

Some studentappreciated this strategy because they could explore

"I over used nitric acid and result did not come as expected. I was scared teacher might scold me but instead

teacher told me to find why expected result did not come… so we can learn something anyway whether right or not"

Some students said they like to learn in this approach but time limitation makes it stressful.

"It was good but takes a lot of time"

"I was quite scared what if I don't do it correctly and thought teacher might scold me"

"It was stressful as it took lot of time planning and discussing"

CHAPTER V
CONCLUSION AND DISCUSSION

5.1 Overview

This chapter presents the interpretation of the research findings and discussion in relation to other research studies. The effectiveness of the developed sol-gel laboratory using inquiry is also discussedwith the conclusion of the study described in the previous chapters. The implication, limitation and recommendationof the study are also discussed here.

5.2 Discussion

5.1.1 Scientific Aspects

All schools in Bhutan follows Bhutanese school curriculum. Bhutanese students take chemistry as a subject from grade IX. Till grade VIII, students study integrated science. The inquiry sol-gellaboratory is designed for students based on constructivist learning environment using 5E inquiry learning approach.The chemical reaction in the learning activity is the reaction of sodium silicate solution and nitric acid to from silica gel. This reaction is an acid-base reaction. The sodium silicate was used for students' practical experiment sol-gel concept because it is easily available in educational chemical stores. It is also stable and not harmful for students to handle. The conditions for the reaction to form the gel were test before implementing with the students by finding out the concentrations to form the gel with the time limit for studying in the class. It was found that the 2%, 5%, 8%, and 10% concentration of sodium silicate solution when reacted with 0.5M of nitric acid formed the silica gel within the time allowable for the experiment by the students in the class. The silica gel formation time ranges from 3 minutes to 20 minutes. The pH of the solution to form

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APPENDICES

APPENDIX A
CONCEPTUAL TEST

Student ID……

Grade……..

Objective: To identify student's understanding of the concepts related to sol-gel Lab.

Part I: Read the question carefully and write the answer.

1. Explain what are differences between gel, liquid and solid?

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2. What is sol?

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What are the mechanisms in the formation of sol-gel?

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3. How does the concentration effect gel formation?

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4. What are factors that affect the gel formation time? How?

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5. Draw the gel structure and explain what you understand?

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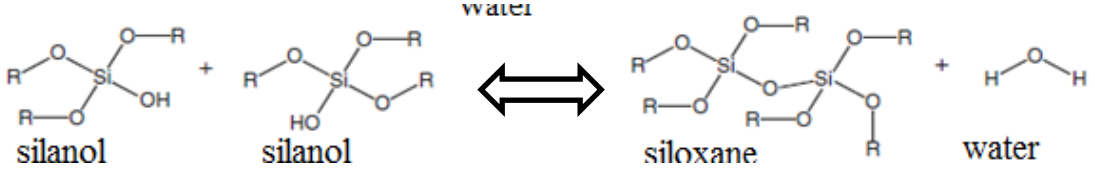
Part II: Read the questions carefully and choose the correct answer from the options given under each question.

1. Which of the following is not a polymer?
    a) Silica
    b) Silicone
    c) Cellulose
    d) Nylon
2. What is sol?
    a) Sol is a solution.
    b) Sol is solid.
    c) Sol is a solid disperse in the solution.
    d) Sol is sediment.
3. Which of the following is an example of sol?
    a) Alcohol
    b) Salt solution
    c) Milk
    d) Oil
4. What type of reaction occurs between sodium silicate and nitric acid?
    a) Decomposition
    b) Neutralization
    c) Condensation
    d) polymerization
5. Why is the solution transparent after adding acid to the solution?
    a. because the acid help to hydrolyze sodium silicate and make the particles in the solution become bigger
    b. because the acid help to hydrolyze sodium silicate and make the particles in the solution become smaller
    c. because the acid help sodium silicate to form a gel network
    d. because the acid prevent sodium silicate to form a gel network

6.



What type of reaction is occurring in the above reaction?

a) Hydrolysis
b) Condensation
c) Neutralization
d) Dissociations

7. What happens to gel formation as concentration of sodium silicate is changed

a) Concentration of sodium silicate solution not affects the gel formation.
b) The rate of gel formation decreases with increase in concentration of sodium silicate solution
c) The rate of gel formation increases with decrease in concentration of sodium silicate solution
d) The rate of gel formation increases with increase in concentration of sodium silicate solution

8. Which of the following is correct?

a) To forming a gel, it start from the silinols occur a hydrolysis reaction.
b) Sodium silicate solution can form gel at only a specific pH.
c) Silica gel is a continuous three dimensional network of nanoparticles spreading throughout the liquid
d) There is only solid inside silica gel.

9. Which of the following is not correct for the sol – gel process?

a) Sol –gel process is the top-down process for making nanomaterials
b) Sol – gel process is the bottom-up approach for making nanomaterials
c) Sol – gel process can use to make powders
d) Sol – gel process can use to make thin film

10. Which of the following is not an application of sol-gel process?
    a) To make an aerogel
    b) To make fibers
    c) To make porous materials
    d) To make pure substances

APPENDIX B
CONSTRUCTIVIST LEARNING ENVIRONMENT SURVEY (CLES) QUESTIONNAIRE

Objective: To determine students' perceptions and preferences in the learning environment before doing sol-gel laboratory

Section 1. Personal Information

Gender □ Male □Female

Student ID…….. Grade……

Section 2. Teaching and Learning Environment in general Chemistry Class

In general chemistry class	Almost always	Often	Sometimes	Seldom	Almost never
1.New learning starts with problems about the world in relevance to my life					
2. What I learn in this class has no relationship to my life.					
3.The concept learned in this class can help me to better understand the world in relevance to my life					
4.I learn that the views of science can change over time					
5. I learn that chemistry knowledge can be applied to be used in different ways.					
6.I learn that science is influenced by peoples values and opinions					
7.I feel free to express my opinion					
8. I feel free to tell teacher about anything that stops me from learning					

Section 2. Teaching and Learning Environment in general Chemistry Class (cont.)

In general chemistry class	Almost always	Often	Sometimes	Seldom	Almost never
9. I can complain about the activities that are confusing.					
10. I help the teacher to plan what I am going to learn					
11. I have a say in deciding the rules for classroom discussion.					
12. I have a say in designing how much time I spend on an activity					
13. I get the chance to share ideas with other students.					
14. I can talk with other students about how to solve the problem.					
15. I ask other students to explain their ideas					
16.I look forward to the learning activities					
17.The activities in this class makes me interested in science					
18. I am confused about the concept learned in this class					
19.The learning activities in this class are waste of time.					
20. I learn interesting things about the world related to my life.					

* Adapted from Taylor and Fraser (1991)

APPENDIX C
SCORING GUIDELINES FOR THE CONSTRUCTIVIST LEARNING ENVIRONMENT SURVEY

This instrument consists of both positive and negative statements which students must answers on scale ranging for almost always to almost never. For positive statement the almost always choice scores 5 and move down to almost never. For negative statements, the scoring procedure is reversed (Salish I Program 1997).

Example:

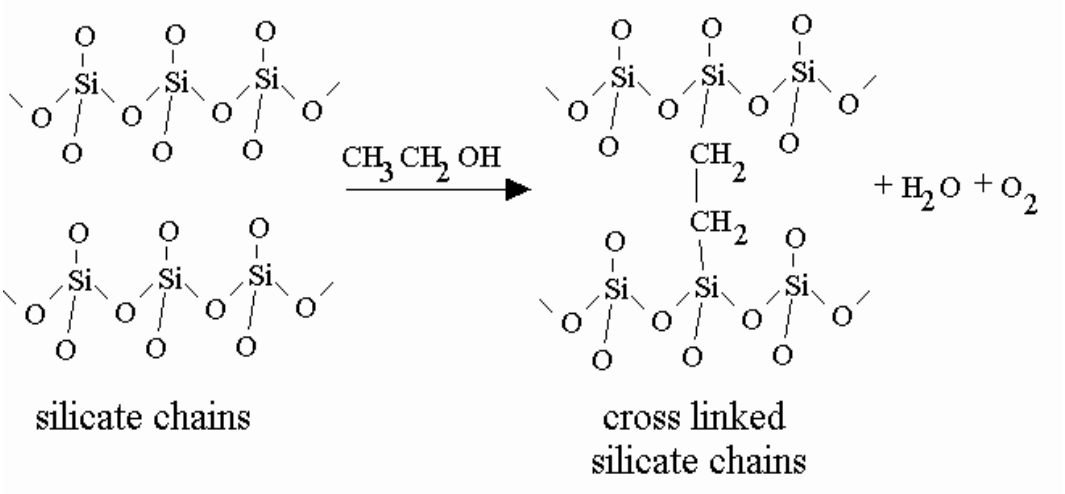
In this class	**Almost always**	**Often**	**Sometimes**	**seldom**	**Almost never**
I look forward to the learning activities	5	4	3	2	1
The learning activities in this class are waste of time	1	2	3	4	5

APPENDIX D

LESSON PLAN

Teacher:
Date: **Time: 3 hours**
Subject / : Chemistry **Grade level:** 10
Materials: Sodium silicate solution, nitric acid, beakers, ethyl alcohol, glass rod, pH paper, measuring cylinders
Lesson Objective(s): 1. Students should be able to explain the sol-gel process and the mechanism to form the gel 2. Students should be able to design and experiment to study the factors that affect the properties of gel and time to form the gel. 3. Students will be able to work cooperatively in groups to seek solutions to solve problem using inquiry method**.**
Strategies to meet diverse learner needs: Inquiry learning
ENGAGEMENT The engagement activity is to engage student to learn about the concept of condensation by using the bouncing ball. Ask students: - What are the properties of polymer? - Can you make a bouncing ball? - Do you want to see how to make a bouncing ball? Teacher demonstrates: Take 50ml of sodium silicate solution (10%) in a beaker and add 10ml of ethanol and stir with popsicle. A solid substance will be formed. Take the solid substance in your hand and squeeze the water out and roll into ball like structure. After the demonstration of the bouncing ball, ask students;

- Why did the two liquids change to solid?
  (When sodium silicate and ethanol are put together, the silicate particlescombine and link up with each other to form long chains as polymer. The ethyl groups of ethanol replace oxygen atoms in the silicate ion.
- What kind of reactionthat make the silicon particles combine to be a bigger particle?
  (When ethanol is added to sodium silicate solution, two oxygen atoms of silicate are replaced by ethyl group of ethanol and loss of water. This reaction is condensation reaction. The results of this reaction is the form of polymer network. The overall reaction is shown below.)



- What is the solid substance formed? (Chain of silicate cross linked)
- Why is the substance bouncing?

(The solid formed is a polymer that has rubber properties. The molecules of polymer have linked up, like network, which can twisted around and have the flexibility property. This makes the ball bounce.)

Teacher notes students' hypothesis (answers) on the chalk board to confirm through discussion later.

Teachers than introduces the topic of the lesson "*sol-gel*".

EXPLORATION

Activity: Group activity **(sol-gel laboratory)**

Teacher first divides the students into 5-6 students each mixed gender. Inform them they will work in the same group until the activity is finished.

Teacher provides the students with the following items in each group.

1. 20ml of 2%, 5%, 8%, and 10% of sodium silicate solution.
2. 150ml of vinegar
3. pH paper

Teacher than explains when vinegar is added to sodium silicate solution and stirred it forms Gel. Then teacher ask students to design the experiment by themselves to study the factors that affect the gel formation. During the activity, teacher asked questions to guide students for conducting the experiment.

EXPLANATION

Students present and explain about their results from the experiment. Teacher asked some questions to help them understand the concept of sol-gel.

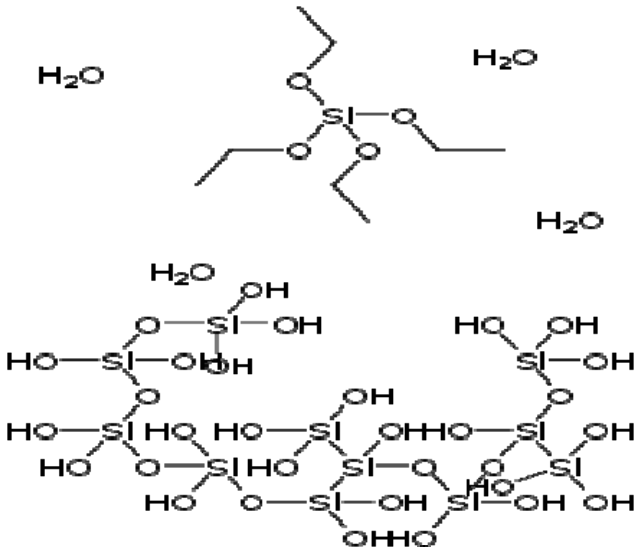
- How did the concentration of sodium silicate effect the gel formation?
  (The rate of gel formation increases with increase in concentration of sodium silicate, because the solution will contain more particles to collide with each other. The formation of gel is fast and the color of gel is not transparent.)
- Does pH have any effect on gel formation?
  (pH affect gel formation time)
- How can you increase the gel formation time?
  (By increasing the concentration of sodium silicate)
- Why is the solution clear in the beginning and visible after adding acid to it?
  (At the beginning, particles in the sodium silicate solution are quite big, when adding acid to sodium silicate solution, the acid help the hydrolyzethe sodium silicate and the particles become smaller. So, the solution become more transparent or more visible after add acid to sodium silicate solution.)
- What kind of reaction taking place during the formation of the gel?
  (The formation of sol-gel starts from the neutralization reaction between

sodium silicate and acid. The result of the reaction is small particles of silicon dioxide. These small particles of silicon dioxide combine with each other and link together to form a continuous three dimensional network spreading thorough out the liquid, forming the gel. The process of the small particle combine together is known as condensation.)

ELABORATION

Teacher post the questions that can help students more about the concept and related concepts and let students discuss in the whole class

- Drawing and explain about the structure of the gel



- What benefit we have from this process in our daily life?

  (Sol-Gel method is widely used in many fields depending on its properties. Many sol-gel derived products have lots of applications. This process is used to produce world's lightest materials and also some of the hardest materials. Sol gel derived products are versatile material of various shapes and structure can be made. This process is the general method use in real industries)

- What do you think about the edible gel? Does it have the same property?

After students presentation, the teacher comments and give necessary feedback and note the important points on the board for final discussion.
Teacher and students discuss and clarify doubts.

EVALUATION

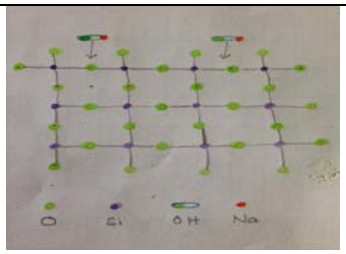
Teacher evaluation students' understanding by asking question and check students' work sheet during the learning activities. After the class discussion, students draw the mind map of the sol-gel concept and the applications of sol-gel. Then, teacher ask selected students to talk what they have learnt from this lesson. How did they feel about the lesson learning through lab activity?

APPENDIX E

CRITERIA FOR SOL-GEL LABORATORY CONCEPTUAL TEST

Questions	Expected answers	Points/Score
1.Explain what the differences between solid, liquid and gel	1) Solid is state of matter that is firm and stable and liquid is also a state of matter but have no fixed shape and not stable. Gel is the material which has some properties like both solid and liquid. It is a solid jelly like material that can have properties varying from soft and weak to hard and tough. The structure of the gel composes of solid and liquid in which the liquid are trapped inside the continuous three dimensional solid networks. The continuous three dimensional solid networks make the gel firm and stable like solid. The liquid inside the gel make the gel soft and weak.	3
	2) Solid is state of matter that is firm and stable and liquid is also a state of matter but have no fixed shape and not stable. Gel is the material which has some properties like both solid and liquid.	2
	3) Solid has stable shape. Liquid have no fixed shape and not stable. Gel is solid jelly like material.	1
	4. No answer or not related to the concept	0
2. What is sol-gel?	1) Sol-gel is a process of forming gel, whichsolid nanoparticles disperse in a liquid agglomerate together to form a continuous three dimensional	3

	network spreading thorough out the liquid 2) A process of forming continuous three dimensional network spreading thorough out the liquid 3) Sol-gel is a process of forming gel 4. No answer or not related to the concept	 2 1 0
3. What is the mechanism in forming sol-gel?	1. The formation of sol-gel starts from the neutralization reaction between sodium silicate and acid. The result of the reaction is small particles of silicon dioxide. These small particles of silicon dioxide collide with each other and link together to form a continuous three dimensional network spreading thorough out the liquid, forming the gel. Process of the small particle link together is known as condensation. 2. Neutralization reaction and condensation 3. Small particles join together to form a network 4. No answer or not related to the sol-gel mechanism	3 2 1 0
4. How does the concentration effect gel formation?	1. The rate of gel formation increases with increase in concentration of sodium silicate, because the solution will contain more particles to collide with each other. The formation of gel is fast and the color of gel is not transparent. 2. The rate of gel formation increases with increase in concentration of sodium silicate solution, because the solution will contain more particles to collide with each other more. 3. The time taken to form gel will be less. 4. No answer or not related to the concept	3 2 1 0

5. What are the factors affecting gel formation time? How?	1.The factors affecting gel formation are 1) Concentration of sodium silicate solution, Higher the concentration of sodium silicate solution the gel forms faster because it contains more silicon dioxide particles 1)pH- different concentration of solution forms gel at different pH and 3)stirring- the more we stir the more particles move and contact each other so bond faster and form gel faster	3
	2.The factors affecting gel formation are concentration of sodium silicate solution, pH and stirring	2
	3. The factor affecting the gel formation is concentration of sodium silicate solution.	1
	4. No answer or not related to concept	0
6.Draw the gel structure and explain what you understand		
	1. The small particles of silicon dioxide join together to form a long chain of three dimensional of solid network thorough out the liquid. Water in the solution fills up the pores inside of the solid network which make the gel soft and jelly like substance.	3
	2. Gel is a solid network long chain of silicon dioxide thorough out the liquid	2
	3. Gel is a solid network long chain of silicon dioxide	1
	4. No answer or not related to the concept	0

APPENDIX F
INTERVIEW QUESTIONS

Content:

1. Explain your understanding about the neutralization reaction.
2. Explain your understanding about sol – gel process.
3. What are differences between solution, sol and gel?
4. Explain how to prepare a transparent silica gel
5. What are parameters that effect the gel formation?

Attitude:

1. Please tell me about yourself? Favorite subject and so on.
2. Tell me about the sol-gel laboratory that you learn in the class today.
3. In what way did you learn in the class?
4. Did this class stimulate your thinking skill? How?
5. Is the learning in this class different from other classes? How?
6. What challenges did you face from learning in this class?
7. Are the activities in this class interesting? How?
8. Does the teacher support you in learning? How?
9. Would you like to learn in this kind of class? Why?
10. Do you think the class can be improved? Why and How?
11. Did you know what was expected from you in the class? Please explain.
12. Overall tell me how did you feel about learning in this class?

APPENDIX G
LABORATORY REPORT

Group ID: ……

Objective:

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Materials:

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Procedures:

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Results

Observing the changes in color and transparency of the samples (from solution to gel)

	Observation			
	sodium silicate solution 2%	**sodium silicate solution 5%**	**sodium silicate solution 8%**	**sodium silicate solution 10%**
Sodium silicate solution				
After adding the 0.5M nitric acid				
At the beginning of forming gel				
After 30 min of forming gel				
pH of the solution after adding nitric acid				
Time taken to form gel				

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Discussion and Conclusion

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BIOGRAPHY

NAME	Namgay Lhaden
DATE OF BIRTH	17March 1979
PLACE OF BIRTH	Thimphu, Bhutan
INSTITUTIONS ATTENDED	National Institute of Education, Samtse, Bhutan Bachelor of Education (2001-2004) Mahidol University, Thailand Master of Science (Science and Technology Education) (2012-2014)
SCHOLARSHIP	Thai International Development Cooperation Agency Thailand
HOME ADDRESS	TakchuGonpa IsuGewog, Haa, Bhutan Tel. 00975-17729080 E-mail:namgaylh@gmail.com
EMPLOYMENT ADDRESS	Lungtenzampa Middle Secondary School, Ministry of Education, Thimphu, Bhutan.
PRESENTATION	Proceedings of the 2nd ASEAN Plus Three Graduate Research Congress (2nd AGRC), Bangkok.