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DEVELOPING A SCIENCE PROCESS SKILLS MODEL IN THE TEACHING OF HIGH SCHOOL CHEMISTRY

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Abstract

The major purpose of this research is to investigate the effectiveness of the proposed science process skills model in the teaching of high school chemistry. The research design adopted in this study was an explanatory sequential (QUAN ⟶ qual) design, one of the mixed methods research designs. The research design for the quantitative study is the nonequivalent control group design, one of the quasi-experimental designs. The participants were Grade Ten students selected from BEHS, Hlegu, No. (4) BEHS Thanlyin, BEHS, Pyalo, and No. (1) BEHS Thayet. For this study, Grade Ten students were selected from each school by random sampling method. These students were assigned into two groups: experimental and control. The two groups were administered a pretest to examine the entry behavior on chemistry basic knowledge. Then, the experimental group was treated with the proposed science process skills model and the control group was taught with formal instruction. After that, a posttest was administered to two groups. As data analysis, a one-way analysis of covariance (One-Way ANCOVA) was used for the quantitative research study. Data collected from interviews were analyzed by thematic analysis for the qualitative research study. Four teachers who taught in the experimental groups and (16) students from the experimental groups were interviewed. The results indicated that the chemistry achievement of students who received instruction by the proposed science process skills model was significantly higher than that of students who did not receive it. Qualitative data supported the findings from the quantitative study. Research findings proved that the proposed science process skills model had a positive contribution to teaching chemistry at the high school level.

Keywords: Science, Chemistry, Basic science process skills, Integrated science process skills, Achievement, Science process skills model

Introduction

In the 21st century, knowledge alone is not enough to prepare students to thrive in the world. Thus, to be effective, learning should include the acquisition of core academic content and higher-order thinking skills. The pedagogy should involve creating, working with others, analyzing, presenting, and sharing both the learning experience and the learned concept. According to Dr. Khin Zaw (2001, a), modern pedagogy must discover ways and means of controlling cognitive activities in the WHOLE aspect and not only by the resulting output.

The students can learn not only conceptual understanding but also procedural understanding. Thus, learning by doing is the central idea of chemistry subject. Chemistry contributes to a large extent in the development and growth of a nation. Myanmar, a developing country, needs many talented chemists. Innovative ideas and thought can emerge through the procedural knowledge of chemistry subject because chemistry is considered an experimental science. The purpose of science education is to empower people to utilize exploratory procedural skills. Science process skills have a great impact on personal, social, and other aspects of an individual’s life. So, teaching integrated with the science process skills tends to not only get conceptual knowledge but also get procedural knowledge.

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Purposes of the Study

The main purpose of this study is to investigate the effectiveness of the science process skills model in chemistry teaching at the high school level. The specific objectives are as follows:

- To develop a proposed teaching model based on science process skills that can enhance students' achievement
- To investigate the effectiveness of the science process skills model in high school chemistry teaching
- To study the attitudes of teachers and students relating to the science process skills model
- To give suggestions based on the data obtained for improving the teaching of chemistry at the high school level

Research Questions

- What are the effects of the science process skills model in the teaching of high school chemistry?
- Are there significant differences between the achievements in learning chemistry of students who received instruction using the science process skills model and those who did not receive it?
- What are the attitudes of teachers and students towards using the science process skills model?

Scope of the Study

The scope of the study is as follows:

- This study is geographically restricted to Yangon Region and Magway Region.
- This study is limited to the selected chapter of Chapter 3: The Electronic Structures of Atoms and Periodic Table, Chapter 4: The Quantities of Substances: Chemical Calculations, Chapter 5: Non-metals: Oxygen, Carbon, and Halogens, and Chapter 6: Acids, Bases, and Salts from Grade Ten chemistry textbook and is conducted in four sample schools in Yangon Region and Magway Region.
- Participants in this study are (201) Grade Ten students from the selected schools within the school year (2020-2021).

Definition of Key Terms

Science: Science is the study of knowing about the universe through data collected by observation and controlled experimentation (Carin & Sund, 1989).

Chemistry: Chemistry may be defined as the branch of science which is concerned with the study of the composition, properties, and structure of matter and the ways in which substances can change from one form to another or react with one another (Ray, 2007).

Basic Science Process Skills: Basic Science process skills contain skills including observation, classifying, measuring, and calculation, using space / time relationships, communicating, inferring, and predicting (Dahsah, Seetee, & Lamainil, 2017).

Integrated Science Process Skills: Integrated science process skills contain skills including formulating hypotheses, defining operationally, identifying, and controlling variables, experimenting, interpreting data, and making inferences (Martin et al., 2005).

Achievement: Achievement is the quality and quantity of a student's work (Webster, 1993).

Science Process Skills Model (Operational Definition): The science process skills model is a teaching model with the integration of both basic science process skills and integrated science process skills to shape the effective teaching-learning process.

Review of Related Literature

Philosophical Foundations

The proposed science process skills model was based on cognitivism and constructivism. Cognitivism uses the metaphor of the mind as a computer because a computer performs the function of information processing and this information can lead to certain outcomes. Changes in behavior are observed as indications of what is occurring in the learner's head. According to the cognitivist perspective, knowledge is approached as schema constructions, and learning is viewed as a change in the learner's schemata or the reconstruction of experience from pre-learning.

Constructivism sees learning as a dynamic and social *process* in which learners actively construct meaning from their experiences in connection with their existing ideas. According to the constructivist perspective, everyone's individual experience makes their learning unique to them. Constructivism is a principle of how people can acquire information best. Young minds create their own understanding and knowledge with respect to their experiences and reflections (Rule & Lassila, 2005). With this perspective, learners are intellectually generative individuals with the capacity to pose questions, solve problems and construct theories and knowledge rather than empty vessels waiting to be filled.

Piaget's Cognitive Development Theory

Kagan (1994) indicates that Jean Piaget's theory of intellectual development is based on the following three assumptions: the main source of a child's knowledge is an activity and by engaging in activities, a child is likely to learn something and gain knowledge about that activity; the major function of knowledge is adaptation.

Piaget's four stages of development are (i) the sensorimotor stage which starts at birth to eighteen months; (ii) the preoperational stage which begins at eighteen months through six and one-half years; (iii) the concrete operational stage which begins at six and one-half years through eleven or twelve years; and (iv) the formal operational stage which starts at eleven years through to adulthood.

Piaget also observed that there are rapid and critical changes in the thinking capabilities of the children as they will have at the stage of the concrete and formal operational level of thinking. Thus, both learning and thinking involve the participation of the learner. The learners must be active. At this formal operational level, the child can carry out classifications of activities, arrange data, generalize, abstract from their experiences, and formulate hypotheses from the results of their observation.

Vygotsky's Sociocultural Theory

Learning occurs in the zone of proximal development. In this zone, the students can perform a task under some guidance and solve the problem independently. Vygotsky's concept of the zone of proximal development is based on the idea that development is defined both by what a child can do independently and by what the child can do when assisted by an adult or a more competent peer. Vygotsky focused on the interaction between people and the sociocultural context in which they act and share experiences.

According to Vygotsky, for the curriculum to be developmentally appropriate, the teacher must plan activities that encompass not only what children can do on their own but what they can learn with the help of others (Karpov & Haywood, 1998, cited in Eggen & Kauchak, 1999). Vygotsky's theory promotes learning contexts in which students play an active role in learning. Roles of the teacher and students are shifted and the teacher should facilitate students in constructing the meaning of knowledge. Thus, learning becomes a reciprocal experience for the student and teacher. When classroom activities are organized, the teachers can plan instruction that can provide practice, cooperative learning activities and scaffolding.

Kolb's Experiential Learning Theory

Kolb (1984) asserted that learning is the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping the concepts and transforming the experience. Kolb's experiential learning theory presents a cyclic model of learning, consisting of four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation.

Concrete Experience (CE): At this stage, learners encounter an experience. The experience can be either a completely new experience or a reimagined existing experience that has already happened. The main key to learning stands in active involvement.

Reflective Observation (RO): After engaging in an experience, learners should step back to reflect on the task or activity. At this stage in the learning cycle, the learner has the opportunity to ask questions from observing facts and discuss the experience with others.

Abstract Conceptualization (AC): Reflective observation heads to abstract conceptualization. In this stage of abstract conceptualization, learners generate abstract ideas or alter their existing concepts based on the reflections that arose from the previous stage. Learners move from reflexive observation to abstract conceptualization when they begin to classify concepts and form conclusions from the events that occurred.

Active Experimentation (AE): After the stage of abstract conceptualization, the last stage of the cycle is active experimentation. At this stage, learners apply their new ideas to real-life situations. This allows them to innovate if there are any changes in the next occurrence of the experience. As such, this stage allows learners to create and test out their new ideas and lessons gathered from past experiences.

Science Process Skills

Since the 19th century, science process skills have played a fundamental role in learners' future skills in the science and technology-related workplace. According to Tobin and Capie **(**1980**)**, 'processes' are intellectual skills that students use in the classroom as they collect and interpret data. Students interact with things in their environment in a scientific manner using science process skills. The science processes are thinking processes that can be applied to any set of problems. The more these process skills are developed, the more learning through their self-activity can be developed.

Science process skills deal with the activities of processes and manipulation of information. Science process skills imply cognitive activity of creating meaning and structure from new information and experiences. Besides, science process skills enable science learners to develop a deeper scientific understanding and stimulate the use of essential scientific data or facts in resolving problems. These skills are the aspect of science learning. Using science process skills is an important indicator of the transfer of knowledge which is necessary for problem-solving for functional living.

Classification of Science Process Skills

The classification of science process skills, according to the American Association for the Advancement of Science (AAAS, 2010), needs to be considered. The curriculum project, Science - A Process Approach (SAPA), has classified the science process skills into two types – basic and integrated. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) process skills. These skills should be assimilated and mastered for a science learner to be grounded on scientific concepts.

Basic process skills are interdependent, implying that more than one of these skills may be displayed and applied in any single activity (Funk et al., 1979, cited in Rambuda & Fraser, 2004). The science process skills include the basic skills like observing, inferring, measuring, communicating, classifying, and predicting (Burchfield & Gifford, 1995). The teacher has a central role to play in encouraging the progression of these basic process skills. The basic science process skills are the basis for learning science.

Integrated process skills are the offshoots of basic process skills. The integrated process skills such as controlling variables, defining operationally, formulating a hypothesis, interpreting data, and experimenting will help to manipulate knowledge in different forms. Scientific thinking is likely to happen on the attainment of integrated process skills.

Description of Proposed Science Process Skills Model

The proposed science process skills model can be described as three instructional phases. They are (1) pre active phase, (2) interactive phase, and (3) post active phase. The different steps operating the process are called the phases of teaching. The first phase in the proposed teaching model is about the planning process, the second phase is for implementing process and the third is assessment. The three main teaching-learning procedures will be briefly described as follows:

Phase (I) Pre active Phase

Pre active phase is the planning and preparation for the process of teaching and learning. There are three steps in this phase. They are (1) orientation of content with intended learning outcomes, (2) assembling appropriate instructional resources and selecting instructional strategies, and (3) engaging prior knowledge. The three steps are connected in a linear process flow. This phase is based on Glaser's basic teaching model, Gerlach and Ely model, Talyzina's cognitivo-cybernetic model, and Ned Flander's interaction analysis model.

Phase (II) Interactive Phase

This phase is implementing the learning process for students. It is especially only for science process skills. This phase includes nine small steps. Among these, seven steps are associated with each other, and the process among these steps is reversible. Two steps are associated in the form of a concept map. Based on the nature of the topic, some science process skills in small steps will be alternatively used. This phase is based on Glaser's basic teaching model, Talyzina's cognitivo-cybernetic model, computer-based model, Ned Flander's interaction analysis model, and Dr. Khin Zaw's multimodal model.

Phase (III) Post active Phase

The post active phase includes drawing conclusions and then, in this phase, the students must show their acquired knowledge. This phase consists of two steps. They are (i) assessment and (ii) feedback. This phase is also based on Glaser's basic teaching model, Gerlach and Ely model, Talyzina's cognitivo-cybernetic model, and the computer-based model.

Method and Procedure

The research design for this study was an explanatory sequential (QUAN ⟶ qual) research design, one of the mixed methods designs. Therefore, quantitative, and qualitative methodologies were used in this study. For the quantitative research methodology, the adopted design was a nonequivalent control group design, one of the quasi-experimental designs. All participants in this study were Grade Ten students and high school teachers. This study was conducted in Yangon Region and Magway Region. Two districts from these regions were randomly chosen. One township from each selected district was also randomly selected. One high school from each township was selected. Participants in this study were selected by random sampling and they were randomly assigned to the experimental group and control group. The experimental group received instruction on the proposed science process skills model and the control group received formal instruction. The achievements of experimental and control groups were analyzed by one-way analysis of covariance (One-Way ANCOVA). The participants for qualitative research were selected by the purposive sampling method. Thus, four students and one high school from each experimental group were selected as participants for the qualitative research methodology. The data collected from interview questions were analyzed by thematic analysis.

Instruments

The instruments used for this study were pretest, posttest, and semistructured interview questions. The instruments were constructed according to the advice and guidance of the supervisor. In order to get validation, the instruments were distributed to nine experts. A pilot study was conducted with (30) Grade Ten students at Basic Education High School, InnTaing in Hlegu Township. After the pilot study, the reliability of the instruments was determined by the value of Cronbach's Alpha coefficient. Pretest was .70 and posttest was .76. A pretest was used to measure the entry behavior of the students. A posttest was used to measure the students' chemistry achievements after treatment by using the science process skills model. The posttest question was constructed based on Bloom's taxonomy of cognitive domain (knowledge level, comprehension level, application level, analysis level, synthesis level, and evaluation level). Test items were constructed based on Chapter 3, Chapter 4, Chapter 5, and Chapter 6 from the Grade Ten chemistry textbook. The allocated time for pretest and posttest was (90) minutes, and the given marks were (54). The test items had choice question items. An interview was conducted to obtain in-depth information on the attitudes of teachers and students who were selected from experimental groups of each selected school. Semistructured interview questions were based on basic process skills and attitudes toward science of Maranan (2017). Semistructured interview questions for teachers consisted of (14) items and semistructured interview questions for students consisted of (15) items.

Results

For quantitative research findings, data were recorded and analyzed systematically. According to the selected quantitative research design, the data from the pretest question were analyzed by using the one-way analysis of covariance (One-Way ANCOVA) to compare the differences between the experimental and the control groups. Pallant (2013) described that ANCOVA is used when the research study has been unable to randomly assign the participants to the different groups but instead has had to use existing groups.

Table 1 Analysis of Covariance (ANCOVA) Results on the Pretest Question

School	Group	N	M	SD	MD	*F*	*df*	Sig. (2-tailed)
School 1	Experimental	22	15.18	2.46	4.34	26.57	39	.000***
	Control	19	10.84	2.93				
School 2	Experimental	29	14.86	4.77	5.49	31.71	57	.000***
	Control	30	9.37	2.34				
School 3	Experimental	28	20.50	2.83	8.89	124	49	.000***
	Control	23	11.61	2.84				
School 4	Experimental	28	16.93	4.18	3.25	10.48	48	.002**
	Control	22	13.68	2.42				

Note. School 1 = BEHS, Hlegu, School 2 = BEHS (4) Thanlyin, School 3 = BEHS, Pyalo, School 4 = BEHS (1) Thayet
***$p < .001$, **$p < .01$

The results showed that there was a significant difference between the entry behavior of experimental groups and control groups in each school. It can be interpreted that there were initial differences between experimental groups and control groups (See Table 1). Therefore, the data from posttest questions were analyzed by using a one-way analysis of covariance (One-Way ANCOVA).

Table 2 Analysis of Covariance (ANCOVA) Results on the Posttest Question

School	Group	N	M	SD	MD	*F*	*df*	Sig. (2-tailed)
School 1	Experimental	22	24.76	3.41	4.69	17.41	38	.000***
	Control	19	20.07	2.93				
School 2	Experimental	29	25.03	3.40	8.95	30.80	56	.000***
	Control	30	16.08	6.09				
School 3	Experimental	28	27.63	3.41	8.59	30.97	48	.000***
	Control	23	19.04	2.93				
School 4	Experimental	28	26.65	2.66	6.43	66.43	47	.000***
	Control	**22**	**20.22**	**2.66**				

Note. ***$p < .001$

The results showed that there was a significant difference between the chemistry achievement of experimental groups and control groups in the four selected schools. It can be interpreted that the proposed science process skills model has a significant effect on the students' chemistry achievements (See Table 2). According to the results, the comparison of mean scores on chemistry achievement is described in Figure 1.

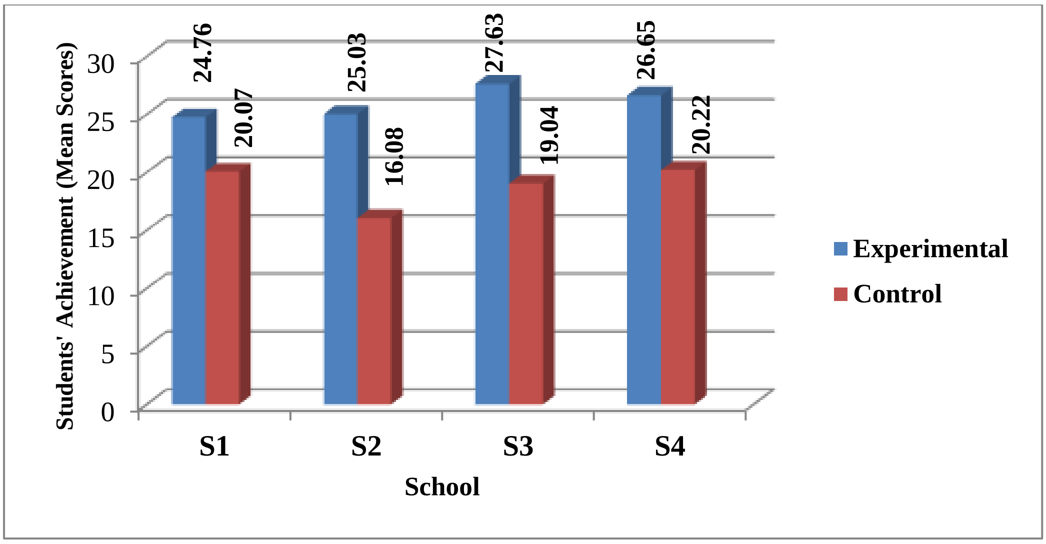

Figure 1. The Comparison of Mean Scores on Chemistry Achievement

Table 3 Summary of One-Way ANCOVA Results on Chemistry Achievement of Students in School 1, School 2, School 3, and School 4

School	Test of Between-Subject Effects					Unadjusted Mean		Adjusted Mean	
	Source	*df*	*F*	Sig. (2-tailed)	Partial Eta Squared	EG	CG	EG	CG
School 1	Pretest	1	14.01	.001	.27	26.00	18.03	24.76	20.07
	Group	1	17.41	.000***	.31				
	Error	38							
School 2	Pretest	1	0.74	.395	.01	25.45	15.67	25.03	16.08
	Group	1	30.79	.000***	.36				
	Error	56							
School 3	Pretest	1	15.40	.000	.17	29.95	16.22	27.63	19.04
	Group	1	30.97	.000***	.20				
	Error	48							
School 4	Pretest	1	6.94	.011	.01	27.04	19.73	26.65	20.22
	Group	1	66.43	.000***	.56				
	Error	47							

Note. EG = Experimental Group, CG = Control Group
***$p < .001$

According to the unadjusted means, there were significant differences between posttest scores of experimental groups and control groups without considering the extraneous variables on these scores. After adjusting the pretest scores, there were significant differences between posttest scores of experimental groups and control groups according to the adjusted mean (24.76, 20.07) and F (1, 38) = 17.41, p = .000 in S1 and the adjusted mean (25.03, 16.08) and F (1, 56) = 30.79, p = .000 in S2, the adjusted mean (27.63, 19.04) and F (1, 48) = 30.97, p = .000 in S3, and the adjusted mean (26.65, 20.22) and F (1, 47) = 66.43, p = .000 in S4. According to the partial eta squared values, there was no significant relationship between pretest scores and posttest scores in the selected schools. Moreover, the partial eta squared values of .31 in S1, .36 in S2, .20 in S3, and .56 in S4 showed the medium effect of the proposed science process skills model on students' achievement. Therefore, the results showed that the use of science process skills had a significant effect on the posttest scores of Grade Ten students in each school (See Table 3).

For qualitative research findings, the data collected from interview questions for teachers and students were analyzed by thematic analysis. According to the results, all the teaching and learning steps in the science process skills model are effective in teaching chemistry. Moreover, practicable and observable teaching aids can promote students' learning. Although group work is well for students' learning, group work activity can be a crisis during the Covid-19 pandemic. Assessment of learning helps teachers to be able to assess learning objectives and students to be able to reflect on their achievements. Based on the data analysis, the emerging themes from the teachers' interviews can be interpreted as follows.

Well preparation*:* Well preparation can create conducive teaching and learning process.

Collaboration: The teachers divide students into groups and motivated them to discuss the lessons. It tends to raise students' collaboration.

Necessities: Basic knowledge about science process skills supports good implementations of the science process skills model. Moreover, fulfilling basic requirements can provide a successful teaching-learning process.

Promoting learning: The words such as "effective," "ease," and "appropriateness" show that the implementation of science process skills in the classroom can promote students learning.

Challenges*:* Language barriers, insufficient time, and individual differences were some difficulties for teachers. Although the implementation of the science process skills model was effective, the teachers had some difficulties in implementation.

According to the research findings on the students' interviews, students got opportunities to observe, inquire and think about the lessons. Knowledge sharing with other members promoted the students' learning. The students participated actively in discussions, group work, predicting activity, observing the lessons, and inquiring about difficult lessons. Based on the thematic analysis, the following emerged themes can be interpreted.

Individual Differences: Some students recognize the teaching steps but some did not. It is because of their attention and intellectual level.

Responsibility for Learning: The students worked in groups and discussed with other members. They also shared knowledge with other students and they actively participated. Decisions together with other members support power-sharing to participate.

Challenges: The students faced some language difficulties, studying with unknown words, and meeting with the new curriculum. They also feared recalling and answering questions at the start of the lessons.

Effectiveness**:** The students understood lessons more than before when they were taught with the use of the science process skills model. They got learning opportunities. They got the facilitation of the teacher in a successful teaching and learning process. Thus, the use of the science process skills model is effective for meaningful learning.

Discussion

According to the comparison of mean scores on posttest questions for all the selected schools, the finding showed that there were significant differences between experimental groups and control groups. This result pointed out that the proposed science process skills model had a significant effect on the chemistry achievement of the students. The science process skills model gives fruitful effects on chemistry at the high school level. This result is consistent with the findings of the study of Abungu, Okere, and Wechanga (2014). They found that the science process skills teaching approach had a significant effect on students' achievement in chemistry.

According to the students' interviews, all students liked the use of the science process skills model in the teaching of high school chemistry. Data from students' interviews were analyzed by thematic analysis. Based on the results, focusing on the main concept, measuring, and experimenting makes lesson contents easy to understand. Practical work turns abstract concepts into concrete concepts. Practical work and experiments are necessary for Myanmar learners because observable facts can help students to absorb abstract concepts. The themes emerging from the responses of students are individual differences, responsibility for learning, challenges, and effectiveness. This study is consistent with Suryanti, Ibrahim, and Lede (2018) who found that the student's interest and positive attitudes toward have increased when the process skills approach is used.

According to the results of the teachers' interviews, all teachers from the experimental groups have many teaching experiences and they all agreed that the teaching and learning steps in the science process skills model are effective in teaching chemistry. Based on the thematic analysis, the five themes emerging from the responses of teachers' interviews are well preparation, collaboration, necessities, promoting learning, and challenges. The teachers also asserted that the science process skills model was effective for productive learning. This result agreed with the findings of Gultepe (2016) that the science process skills have a positive effect on the teaching of science and class activities with science process skills promote conceptual learning.

Suggestions

With respect to the research findings, the following suggestions should be considered for the use of the science process skills model to be more effective in teaching chemistry.

Suggestions for Teachers: The teacher should collect and prepare teaching resources such as observable flashcards, pictures, and other visual materials. The teacher should facilitate the difficulties and challenges of students when learning with the science process skills. The teacher should understand the processing function of the human brain and cybernetic function. Finally, the teacher should manage time to create an effective teaching-learning process.

Suggestions for Students: The students should ask for unfamiliar and unknown words. The students should have adaptive thinking in order to pull out innovative ideas.

Suggestions for School Administrators: The school administrators should realize the teaching-learning situation and working atmosphere. They should support the teaching resources which will be useful in the teaching-learning process.

Recommendations

Some recommendations for further study are as follows:

- In this study, sample schools were randomly selected from Yangon Region and Magway Region. Thus, further research studies should be carried out in the rest of the States and Regions by using different participants for replication.
- In this study, the content areas were limited to Grade Ten chemistry textbook. So, further study should be carried out for the other content areas at the high school level.

- In this study, the proposed science process skills model was developed for the high school level. Further research should be carried out for various school levels such as primary school level and middle school level.

Conclusion

This study indicated that the implementation of the science process skills model in the teaching of high school chemistry encourages students' collaboration and promotes students' learning. Thus, it can be regarded that the proposed science process skills model has a positive impact on chemistry achievement.

Teaching higher-order thinking skills is at the center of the educational aspect. Classroom teaching should be related to everyday experience. Inconsistent with the changing world, innovative teaching must be combined into everyday classroom teaching. Without taping the students' knowledge, the teacher should teach a more coherent and thoughtful understanding of the concept. Indeed today, outside the classroom, the student may be in a richer informational environment than he is inside the conventional classroom (Khin Zaw, 2001, b).

The present study provided a better approach for teachers in the teaching of high school chemistry. But the teachers should increase their knowledge about the science process skills to keep students engaged and motivated during the learning process. It consists of the teaching steps relating to the science process skills. The role of science process skills is important to develop higher-order thinking skills and practical skills. These process skills should be prepared to adapt to the sophisticated environment designed by 21st century skills. Meanwhile, it is concluded that the use of the proposed science process skills model in the chemistry subject is effective for teachers and students.

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