AN ANALYTICAL STUDY OF THE IMPACT OF INQUIRY-BASED LEARNING ON STUDENTS' INQUIRY PROCESS SKILLS IN TEACHING HIGH SCHOOL BIOLOGY

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Abstract

The main purpose of this study is to investigate the applicability of inquiry-based learning (IBL) that can enhance students' inquiry process skills in teaching and learning high school biology in Myanmar. Inquiry-based learning was implemented using Biological Science Inquiry Model (BSIM). A mix-method: QUAN □ qual design was used. For quantitative research, the research design was nonequivalent control group design. Simple random sampling method was used. This study was conducted in four basic education high schools from Yangon Region. The instruments were pretest, posttest, lesson plans, materials, questionnaires and observation checklists. The quantitative research findings include three main parts. Firstly, there was a significant difference in biology achievement between students who received IBL and those who did not. Secondly, the stronger the inquiry process skills were developed, the higher the biology achievement. Thirdly, the predicting factors were observing, hypothesizing, questioning, communicating, classifying and experimenting. For qualitative research, case study research design was used. Random purposive sampling method was used. Regarding qualitative research findings, teachers and students preferred and well performed on inquiry process skills through IBL according to the results of questionnaires and observation checklists. Therefore, inquiry-based learning contributed a positive impact on teaching high school biology. The research findings suggested that IBL should be used in teaching and learning high school biology in Myanmar.

Key words: Inquiry, Inquiry-based Learning, Inquiry Process Skills, Teaching, Biology

Introduction

The process of education needs to be adapted to the changing needs of the society and the aim of education must be to equip the individual or the nation for the struggle so as to ensure survival. Similarly, the meaning of education is to draw out something and not to put in something. The meaning of education gives educators the concept of learner-centered rather than teacher-centered education. It is necessary to change ideas, thoughts and teaching methods that lead to learner-centered education. Therefore, this research was conducted with more emphasis on learner-centered rather than teacher-centered education.

In Myanmar, pedagogues and teachers need to learn the methodology of teaching students to improve thinking skills. With this in mind, this research is an attempt to develop inquiry process skills with the practical aspects of biological science inquiry activities suggested in this research.

Objectives of the Research

1. To investigate the applicability of IBL that can enhance students' inquiry process skills in teaching and learning high school biology.
2. To explore the attitudes and opinions of teachers and students who participate in this study.
3. To analyze students' inquiry process skills by applying inquiry-based learning and give suggestions for the improvement of teaching and learning biology.

Research Questions

1. Are there any significant differences in biology achievement of the students who received IBL and those who did not?
2. Are there any significant relationships between students' biology achievement and their attitudes towards inquiry process skills?

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3. Do inquiry process skills predict biology achievement?

Scope of the Research

1. This study is geographically restricted to Yangon Region.
2. Participants in this study are Grade Ten biology students from the selected schools in the academic year (2018-2019).
3. As valid content areas, this study deals with seven topics prescribed in Grade Ten biology textbook.

Definitions of Key Terms

Inquiry. Inquiry is the process of defining and investigating problems, formulating hypotheses, designing experiments, gathering data and drawing conclusions about problems (Bybee &Trowbridge, 1990).

Inquiry-based Learning. Inquiry-based learning (IBL) is a pedagogical approach that engages learners actively in a knowledge-building process through the generation of answerable questions (Harada & Yoshina, 2004).

Inquiry Process Skills. Inquiry process skills are involved in the context of the progression of inquiry. Science is about the process of seeking explanations through a progression of inquiry: descriptive modeling, explanatory modeling, and experimental modeling **(**Abruscato & Derosa, 2010).

Teaching. Teaching refers as an activity or process which is related with the impact of certain specific knowledge or skill, guiding and assessing, with the aim of assisting students to learn effectively (Sang, 2003).

Biology. Biology (bios, life; logos, knowledge) is a science devoted to the study of living organisms (Taylor, Green & Stout, 1997).

Statement of the Problem

Firstly, the major challenges for teachers in Myanmar are to meet the minimum learning standard at the national level and to learn to think critically and creatively. The problem is ‘how to teach’ to develop the thinking skills. Some teachers have fewer opportunities to create teaching-learning activities to develop their students’ higher-order thinking skills. Biology has both biological concepts – the content of biology and inquiry, which is “how students think about what they know, why they know and how they have come to know” – the process of biology (inquiry process skills). This research emphasizes both biological concepts and process by using biological science inquiry activities to develop higher-order thinking skills and inquiry process skills rather than memorization of biological concepts.

Secondly, the first aim of teaching biology at the high school level is to develop an understanding of essential biological principles based upon an elementary knowledge of living organisms. To understand the biological knowledge of plants and animals, biology students recognize the distinction between looking and observing. Observing means using the sense to obtain biological knowledge. It is the most basic inquiry process skills of biology. Based on this requirement, this research highlights inquiry process skills in teaching and learning biology.

Thirdly, the fifth aim of teaching biology at the high school level is to be able to assess and interpret simple biological experiments and data. Therefore, it is essential for biology teachers to develop inquiry process skills such as experimenting skills in students. Based on this requirement, this research emphasizes to enhance all integrated inquiry process skills both in the classroom and in the laboratory. Therefore, biology teachers need to cultivate these inquiry process skills for their students because of the changing nature of biological science and the consequent need for new educational goals.

Based on the nature of biology and the aims of teaching biology at basic education high school level in Myanmar, IBL focuses on not only by means of classroom instruction but also by means of experiments in a laboratory.

Review of Related Literature

Philosophical Considerations: Progressivism, naturalism, pragmatism and constructivism are deeply taken into philosophical considerations for inquiry-based learning.

Firstly, progressivism is taken into philosophical consideration for inquiry-based learning. For progressives, learning is the continual reconstruction of experience. Experience and experiment are two key words for the progressives. According to Jewey, learning was always an active process; the brain was not a passive receiver of knowledge but an active participant in or originator of meanings through problem solving (Dewey, n.d., cited in Ozmon & Craver, 1986). In inquiry-based learning, the implementing phase emphasizes how students should think in teaching and learning biology.

Secondly, education finds its purpose, its process, and its means wholly within the child life and the child experience. Schools seek to provide the ideal environment of freedom for the development of the growing child (Ross, 1941). As pointed by Dhiman (2007), good education can be had only by a direct contact with nature. In methods of teaching, naturalism emphasizes activity and learning by doing. So, learner-centered approach is the characteristics of the naturalists' philosophy. Similarly, inquiry-based learning is an inductive approach and learner-centered approach and a cooperative climate is desired.

Thirdly, pragmatism is a philosophy that stresses the intimate relation between thought and action by defining the meaning of the conceptions in terms of the practical effects and the truth of the beliefs in terms of how successfully they guide the actions (Lawhead, 2011). 'Learning by doing' is an important corollary of pragmatism in educational method (Ross, 1941). In the inquiry-based learning, the implementing phase focuses on learning activities to think about and solve the investigated problem.

Fourthly, constructivist philosophy maintains that only an individual's interpretation of the world matters and that everyone constructs their own view of reality (Alessi & Trollip, 2001). Constructivism is an approach to learning which emphasizes that individuals actively construct knowledge and understanding (Santrock, 2006). In the inquiry-based learning, the implementing phase emphasizes students to construct knowledge and understanding in their own mind.

Learning Theories: Piaget's cognitive learning theory and Vygotsky's cultural-historical theory are deeply taken into considerations for inquiry-based learning.

Firstly, knowledge is a process that is created by the activity of the learner in Piaget's cognitive learning theory (Pufall, 1988, cited in Gredler, 2001). The concepts developed by Piaget can be implemented in classrooms by providing rich activities for student's exploration. Students are encouraged to solve problems in ways that make sense to them, to be able to justify and explain their answers and to participate in class discussion to resolve conflicts and confusion. In inquiry-based learning, students observe their answers by participating learning activities. They identify answers in the investigation.

In Vygotsky's cultural-historical theory, essential in classroom instruction to develop higher cognitive functions is the collaboration between teacher and student (Gredler, 2001). Inquiry-based learning focuses on human interaction by carrying out inquiry and students are grouped during instruction.

Inquiry-based Learning. Inquiry-based learning was implemented using Biological Science Inquiry Model (BSIM). This model has four phases: plan, assess, implement and evaluate.

Biological Science Inquiry Model

In Biological Science Inquiry Model, there are four main components (see Figure 1).

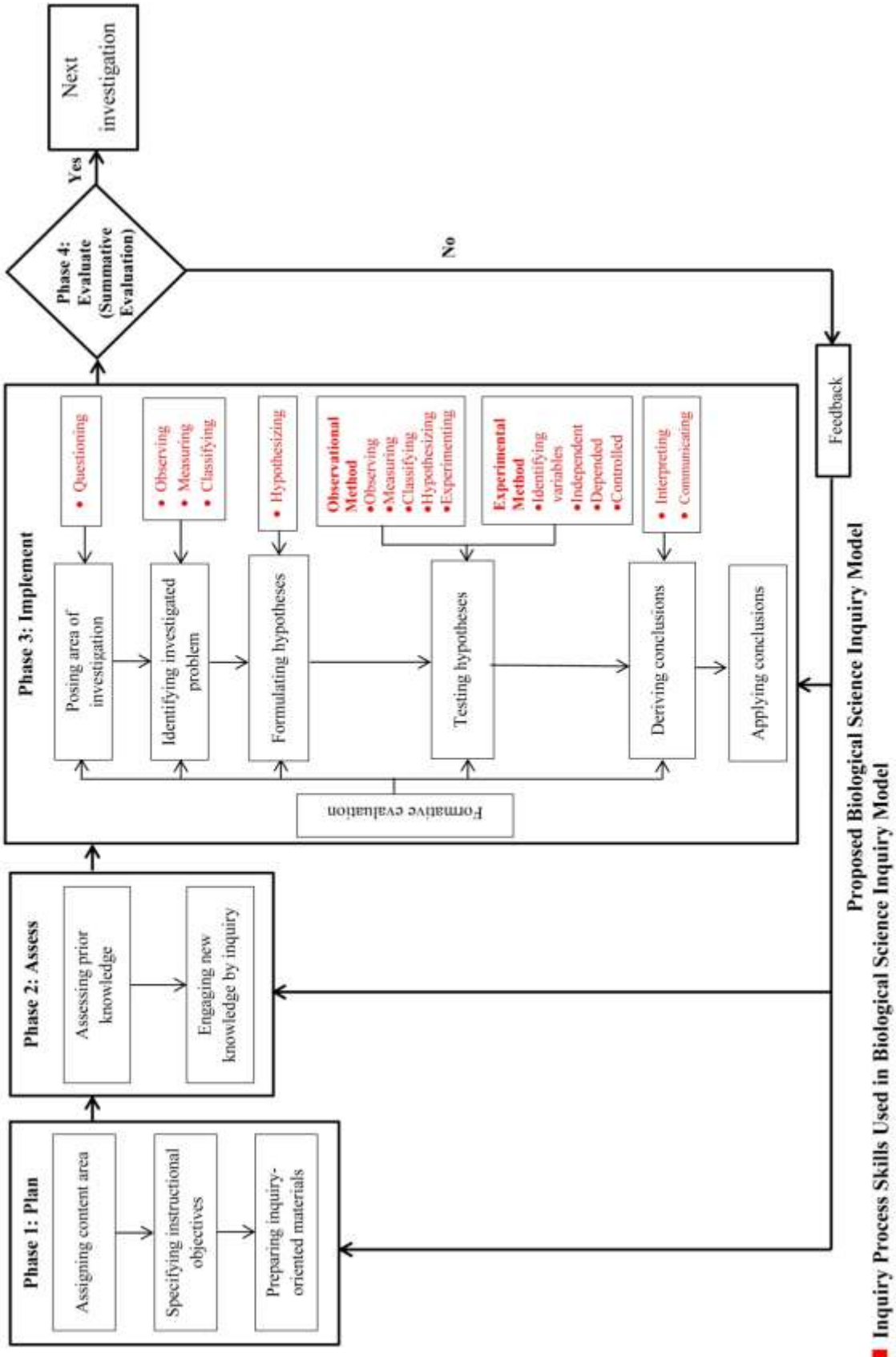

Figure 1 Biological Science Inquiry Model for Teaching High School Biology

Methods

Research Design. The research design adopted in this study was explanatory sequential (QUAN → qual) design, one of the three basic mixed methods designs.

Quantitative Research Design. The research design used in this study was nonequivalent control group design.

Population and sample. Simple random sampling method was used. Table 1 shows population and sample of the quantitative study.

Table 1 Population and Sample for Quantitative Research

Region	District	Township	Name of School	No. of Population	No. of Sample
Yangon	East	Yankin	No.(2) Basic Education High School, Yankin	201	107
	West	Kamayut	No.(5) Basic Education High School, Kamayut	178	105
	South	Kyauktan	No.(2) Basic Education High School, Kyauktan	142	107
	North	Hlegu	Basic Education High School, Hlegu	145	100
Total				666	419

Qualitative Research Design. The research design used in this study was case study research design. Random purposive sampling, one of the qualitative sampling approaches, was used for this qualitative study.

Instruments. Pretest, materials or lesson plans, posttest, questionnaires and observation checklists were used as instruments. The instruments based on inquiry process skills.

Analysis of Data. The Statistical Package for the Social Sciences (SPSS) Version 22 was used to analyze the data. The data were analyzed by using one-way analysis of covariance, Pearson product-moment correlation and multiple regression.

Findings

Quantitative Research Findings

Findings of Biology Achievement

Findings of biology achievement include three research questions.

Analysis of the Posttest Scores. The first research question is "Are there any significant differences in biology achievement of the students who received IBL and those who did not?" To answer this research question, one-way ANCOVA was used to analyze the data from posttest scores.

From each school, the two intact groups were selected as the experimental group who received IBL and the control group who did not. As pointed out by Pallant (2013), ANCOVA is used when the study has been unable to randomly assign the participants to the different groups, but instead has had to use existing groups.

Table 2 shows the results of pretest scores in the four selected schools.

Table 2 Results of Pretest Scores in Four Schools

School	Group	N	M	SD	MD	MS	*F*	*p*
S1	Experimental	53	19.87	2.01	−.72	14.05	2.300	.132 (ns)
	Control	54	20.59	2.85				
S2	Experimental	52	17.12	4.24	.93	22.54	1.485	.226 (ns)
	Control	53	16.19	3.53				

School	Group	N	M	SD	MD	MS	*F*	*p*
S3	Experimental	54	20.06	2.38	.98	25.69	4.813	.030*
	Control	53	19.08	2.24				
S4	Experimental	50	17.16	4.17	−.20	1.00	.059	.808 (ns)
	Control	50	17.36	4.04				

Note. S1 = No. (2) Basic Education High School, Yankin; S2 = No. (5) Basic Education High School, Kamayut; S3 = No. (2) Basic Education High School, Kyauktan; S4 = Basic Education High School, Hlegu.

*$p < .05$. ns = not significant.

Table 3 shows the analysis of covariance results for posttest scores in the four selected schools.

Table 3 Analysis of Covariance Results for Posttest Scores in Four Schools

School	Group	N	M	SD	MD	MS	*F*	*p*
S1	Experimental	53	35.04	1.79	9.71	2438.39	246.550	.000***
	Control	54	25.33	4.04				
S2	Experimental	52	23.87	3.54	5.42	729.19	40.171	.000***
	Control	53	18.45	4.87				
S3	Experimental	54	29.74	3.88	6.82	1103.22	72.52	.000***
	Control	53	22.92	3.97				
S4	Experimental	50	31.68	4.65	14.76	5432.28	225.226	.000***
	Control	50	16.92	5.13				

*Note.*S1 = No. (2) Basic Education High School, Yankin; S2 = No. (5) Basic Education High School, Kamayut; S3 = No. (2) Basic Education High School, Kyauktan; S4 = Basic Education High School, Hlegu.

***$p < .001$.

The results of posttest scores in the four schools showed that the mean scores of the experimental groups were significantly higher than those of the control groups (see Table 3). Therefore, it can be interpreted that the application of IBL had a significant effect on the biology achievement of students. According to the ANCOVA results of posttest scores in the four schools, Figure 2 is illustrated.

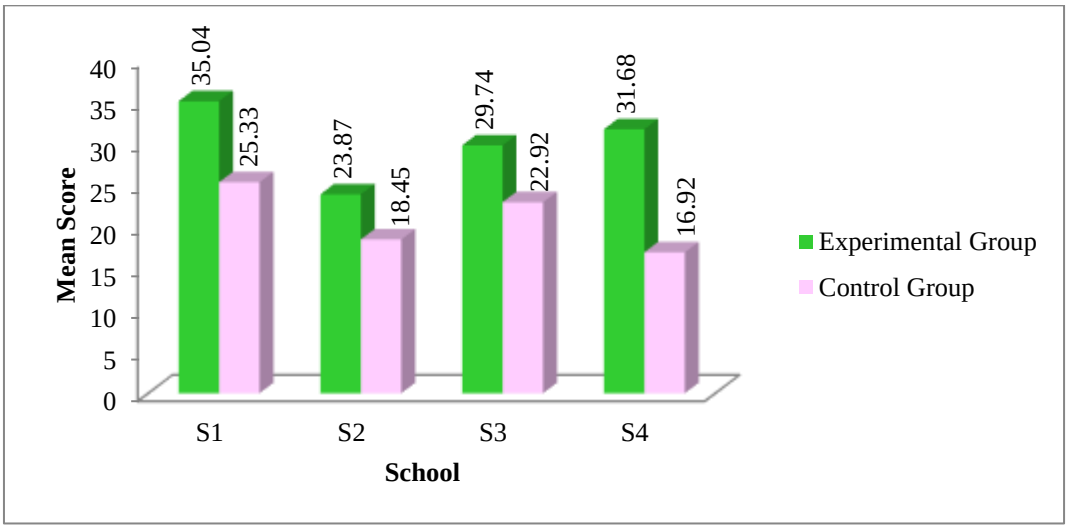

Figure 2 Comparison of Posttest Mean Scores in Four Schools

Relationship between Biology Achievement and Attitudes towards Inquiry Process Skills

The second research question is "Are there any significant relationships between students' biology achievement and their attitudes towards inquiry process skills?" To answer this research question, Pearson product-moment correlation was used.

According to Mertler and Vannatta (2002), the Pearson product-moment correlation (r) measures the association between two quantitative variables without distinction between the independent and dependent variables.

Table 4 Correlation between Biology Achievement and Attitudes towards Inquiry Process Skills

	Biology Achievement	Questioning	Observing	Measuring	Classifying	Hypothesizing	Experimenting	Interpreting	Communicating
Biology Achievement	1	.760**	.769**	.280**	.715**	.750**	.649**	.291**	.758**
Questioning		1	.819**	.369**	.669**	.692**	.550**	.534**	.774**
Observing			1	.346**	.677**	.616**	.526**	.474**	.731**
Measuring				1	.365**	.349**	.251**	.600**	.429**
Classifying					1	.646**	.499**	.184**	.696**
Hypothesizing						1	.728**	.298**	.743**
Experimenting							1	.238**	.599**
Interpreting								1	.434**
Communicating									1

Note. **Correlation is significant at the 0.01 level (2 – tailed).

According to the result of Table 4, it showed that biology achievement was significantly correlated with all inquiry process skills.

According to Cohen's guideline (1988, cited in Pallant, 2013), the strength of correlation from r = .10 to .29 is small, the strength of correlation from r = .30 to .49 is medium and the strength of correlation from r = .50 to 1.0 is large. From the Pearson correlation analysis, there was a large correlation between biology achievement and questioning, observing, classifying, hypothesizing, experimenting and communicating (r = .50 to 1.0), suggesting quite a strong relationship between biology achievement and questioning, observing, classifying, hypothesizing, experimenting and communicating. However, there was a weak correlation between biology achievement and measuring and interpreting (r = .10 to .29), suggesting quite a weak relationship between biology achievement and measuring and interpreting. From this result, it could be generally interpreted that students with inquiry process skills could contribute to the high biology achievement of the students.

Regression Analysis of Predictions of Inquiry Process Skills for Biology Achievement

The third research question is "Do inquiry process skills predict biology achievement?" To answer this research question, multiple regression analysis was used.

As pointed out by Creswell (2002, p.372), "multiple regression is a statistical procedure for examining the combined relationship of multiple independent variables with a single dependent variable." Table 5 shows the regression analysis summary for the variables predicting biology achievement.

Table 5 Regression Analysis Summary for the Variables Predicting Biology Achievement

Variables	**B**	**β**	**t**	**R**	**R^2**	**Adj R^2**	**F**
Biology Achievement	9.484		7.817***	.872	.761	.752	79.661***
Predictor Variables							
Questioning	.425	.156	2.104*				
Observing	.808	.301	4.585***				
Measuring	−.154	−.048	−.998				
Classifying	.536	.139	2.375*				
Hypothesizing	.796	.201	3.148**				
Experimenting	.605	.131	2.563*				
Interpreting	−. 230	−.089	−1.637				
Communicating	.490	.151	2.292*				

Note. Constant = Dependent variable : Biology Achievement.

*$p < .05$. **$p < .01$. ***$p < .001$.

The result of multiple regression analysis pointed out that inquiry process skills such as questioning, observing, classifying, hypothesizing, experimenting, and communicating made a significant predictive contribution to high students' biology achievement (t = 7.817, $p < .001$). The results in Table 5 stated $R^2 = .761$, F = (8, 200) = 79.661 and $p < .001$. The adjusted R square value is .752. This indicated that approximately 75.2% of the variance in biology achievement can be predicted from attitudes towards inquiry process skills: questioning, observing, classifying, hypothesizing, experimenting, and communicating.

The equation for predicting the biology achievement from the students' attitudes towards inquiry process skills can be defined as follows.

BA = 9.484 + .425X1+ .808X2 + .536X3+ .796X4+ .605X5+ .490X6

BA = Biology Achievement

X1 = Questioning

X2 = Observing

X3 = Classifying

X4 = Hypothesizing

X5 = Experimenting

X6 = Communicating

Based on the result of multiple regression analysis, among inquiry process skills, observing was the best predictor of the inquiry process skills (β = . 301***, $p < .001$). The second predictor was hypothesizing (β = . 201**, $p < .01$), the third predictor was questioning (β = . 156*, $p < .05$), the fourth predictor was communicating (β = .151*, $p < .05$), the fifth predictor was classifying (β = . 139*, $p < .05$) and the last predictor was experimenting (β = . 131*, $p < .05$). Based on the multiple regression analysis presented above, the multiple regression model of inquiry process skills for biology achievement is shown in Figure 3.

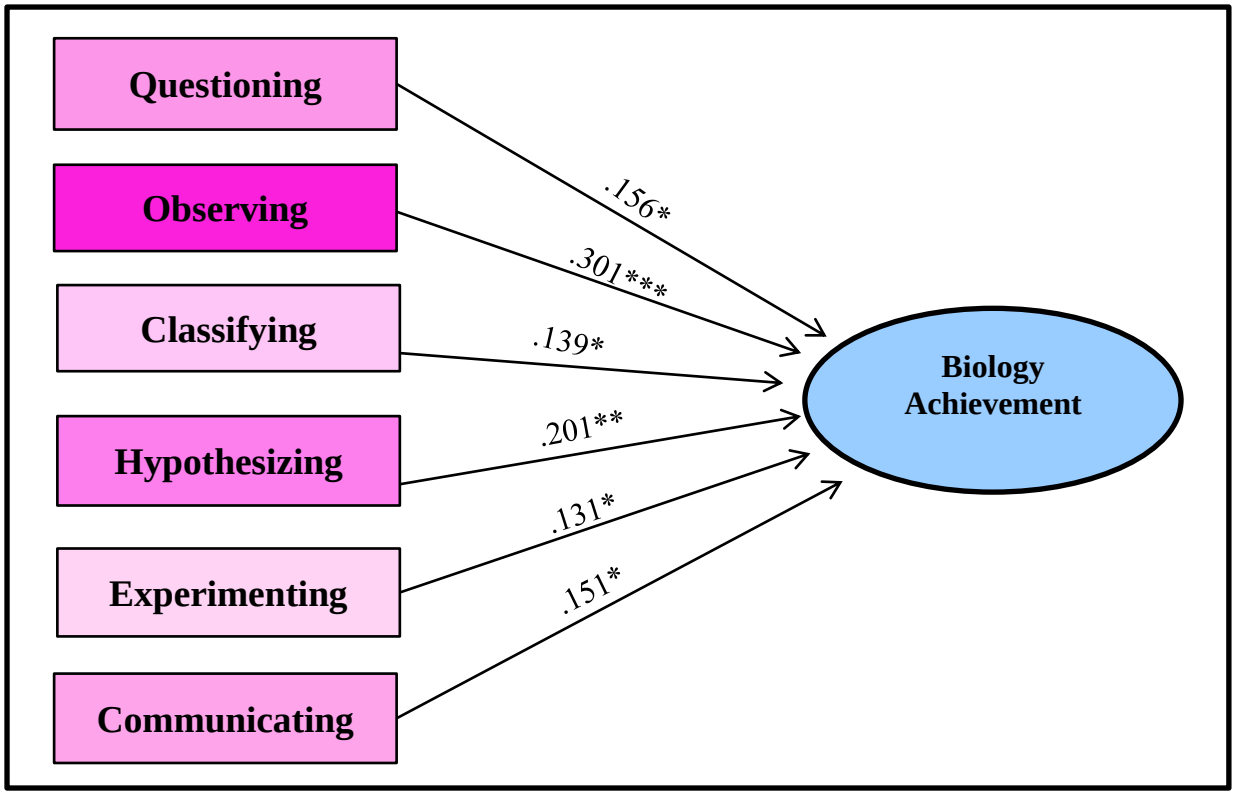

Figure 3 Multiple Regression Model of Inquiry Process Skills for Biology Achievement

According to Pallant (2013), multicollinearity exists when the independent variables are highly correlated (r = .9 and above). In this research, the independent variables are not highly correlated (below r = .9) to avoid multicollinearity (see Table 4). In the Normal P-P Plot, points lied in a reasonably straight diagonal line from bottom left to top right. This would suggest no major deviations from normality in this research. Since there is no multicollinearity and normality, it is reasonable to conclude that the multiple regression model to explain biology achievement is stable, good and quite respectable.

Qualitative Research Findings

Research Findings from Questionnaire. The qualitative data analysis showed that all teachers and most of the students developed positive attitudes towards inquiry process skills.

Research Findings from Teachers' Observation Checklist. The evidence from the observation checklists stated that teachers performed better in inquiry process skills when they have more teaching experiences.

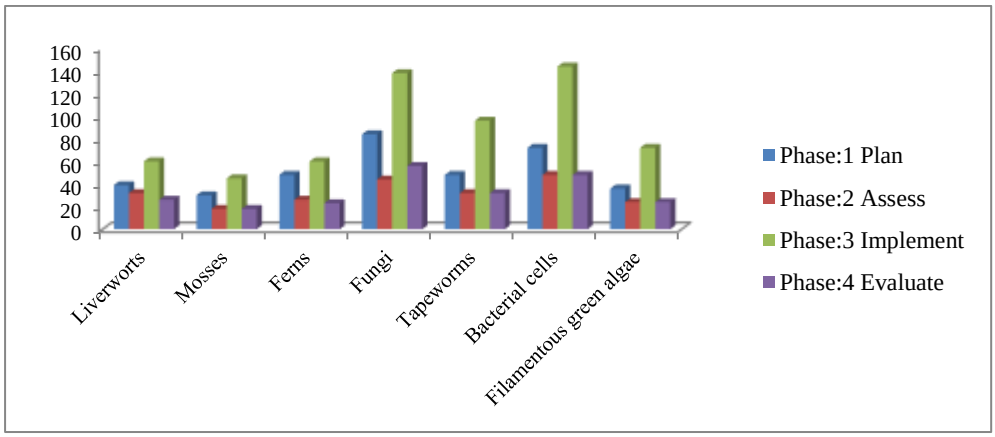

Figure 4 Graphic Illustration of Teachers' Observation Checklist on Biology Lessons

Research Findings from Students' Observation Checklist. The checklist expressed that students displayed better inquiry process skills when they have more learning experiences.

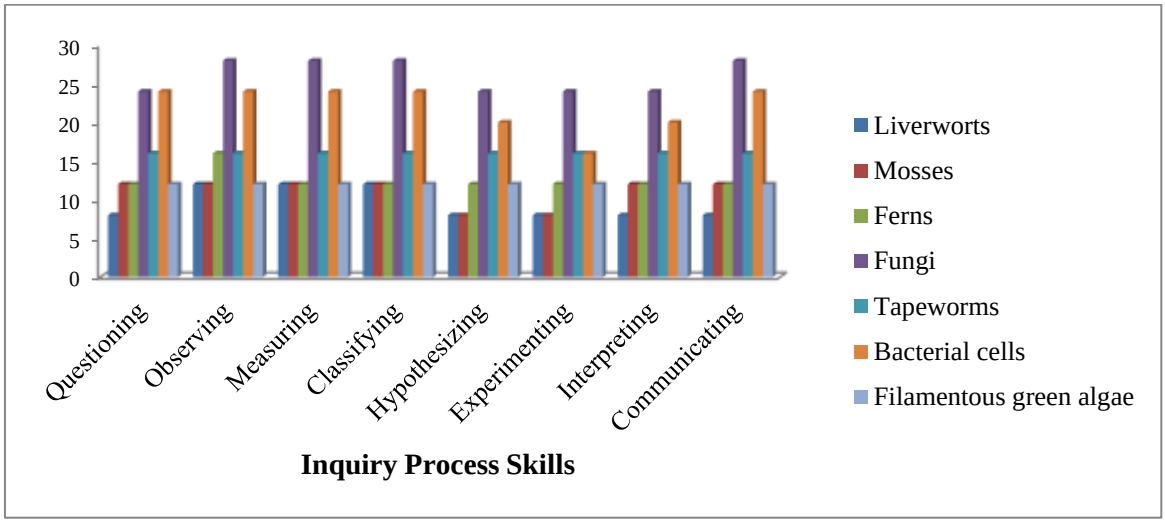

Figure 5 Graphic Illustration of Results of Students' Observation Checklist on Biology Lessons

Discussion

The first objective of this research is to investigate the applicability of inquiry-based learning that can improve students' inquiry process skills in teaching and learning high school biology. Based on the research findings, the experimental groups who received IBL performed significantly higher than the control groups who did not receive it in all schools. This result shows that the experimental groups could get more biology achievement than the control groups. Therefore, it can be interpreted that the application of IBL had a significant effect on the biology achievement of all schools.

The second objective is to explore the attitudes and opinions of teachers and students who participate in this study. To examine the relationship between students' biology achievement and their attitudes towards inquiry process skills, Pearson product-moment correlation was used. According to this result, there were significant relationships between biology achievement and all inquiry process skills: questioning, observing, measuring, classifying, hypothesizing, experimenting, interpreting and communicating. Among them, questioning, observing, classifying, hypothesizing, experimenting, and communicating were strongly correlated with biology achievement. However, measuring and interpreting were weakly correlated with biology achievement. Therefore, it can be interpreted that the stronger the inquiry process skills were developed, the higher the biology achievement.

According to Gibson and Chase (2002), inquiry based activities were influenced in students' having positive attitudes towards science learning. In a similar vein, Chen, Wang, Dede and Grotzer (2007) also concluded that the students' attitudes towards inquiry learning were quite positive. This was also evident from their interview data. In addition, during the free discussion between the researcher and the participants after the experiment, most students revealed that the inquiry learning approach was very interesting, stimulating their passions in exploring the problem and made them become active in learning. The above research findings were consistent with the results of this study.

To explore the predicting factor of attitudes towards inquiry process skills, multiple regression was used. From the regression anslysis, inquiry process skills such as questioning, observing, classifying, hypothesizing, experimenting, and communicating were significant predictors for biology achievement. Among inquiry process skills, observing was the best predictor of the inquiry process skills. The second predictor was hypothesizing, the third

predictor was questioning, the fourth predictor was communicating, the fifth predictor was classifying and the last predictor was experimenting. These findings showed that the students who had high questioning, observing, classifying, hypothesizing, experimenting, and communicating skills had high biology achievement. From this result, experimenting got the last ranking skill. So, it can be interpreted that students should do many experiments to know cause and effect relationships among biological concepts.

The third objective of this research is to analyze the improvement of inquiry process skills by applying inquiry-based learning. Concerning inquiry process skillls, the experimental groups were significantly higher than the control groups in all schools. Therefore, it can be interpreted that the application of IBL can develop inquiry process skills. Based on the disscussion obtained, it can be concluded that the application of IBL had a positive impact on biology students' inquiry process skills.

Suggestions

The first portion is suggestion for teachers. It was found that most of the biology teachers agreed that they asked the students to observe their instruction by using teaching aids. As a result, students will be able to answer all the questions that are posed to them (observing). Therefore, it is suggested that biology teachers should be provided with teaching aids, real plants and animals, preserved specimens and inquiry-oriented materials, especially electron microscopes.

According to Liu, Lee and Linn (2010), teachers who use inquiry learning can produce students who have a high level of knowledge. According to the research findings, it was found that teachers and students developed positive attitudes towards inquiry process skills. Therefore, it is suggested that teachers should use inquiry process skills to develop biological concepts among students.

The second portion is suggestions for students. Concerning students' attitudes towards inquiry process skills, it was found that students developed positive attitudes towards inquiry process skills, especially observing. This is due to the fact that most of the biology students agreed that they liked learning biology taught by means of IBL because it enhanced their longer retention of the content areas of the lessons as a result of being given an opportunity to make inquiry and learn by using all the five senses including sight, hearing, smell, taste and touch (observing). Therefore, it is suggested that biology students should be provided with teaching aids, real plants and animals, preserved specimens and inquiry-oriented materials, especially electron microscopes.

According to the research results of the predictors of inquiry process skills in biology achievement, the best predictor was the observing skill and the last predictor was the experimenting skill. These findings pointed out that students had less experience in experimentation. Therefore, it is suggested that students should do many experiments as possible to develop experimenting, thinking and reasoning skills.

In Myanmar, biology is taught at the high school level. However, biological concepts such as living things are taught as a science subject with Myanmar language from primary to middle school levels. As a result, biology teachers from primary to high school levels should prepare lesson plans based on IBL to improve inquiry process skills.

According to research findings of observation checklist, students could not achieve well in all inquiry process skills at the initial biology lessons because they were not familiar with inquiry process skills. However, students could achieve gradually all inquiry process skills at the final lessons according to their learning experiences. Thus, it is suggested that biology teachers should emphasize on the development of inquiry process skills right from the primary school level to improve inquiry process skills. To have been familiar with inquiry process skills,

students should be taught with inquiry-based learning not only in biology but also in science from primary to high school levels.

Recommendations

The results of this research contributed to the improvement of teaching and learning biology at the high school level in Myanmar. But, it is not perfect for all situations. Therefore, it is necessary to conduct further research. Since all data in this research were collected from Yangon Region, it may have limitations to the generalizability of findings. So, further research should be carried out in the other states and regions. In this study, the participants were only Grade Ten students. In fact, biology is taught in both Grade Ten and Grade Eleven. Therefore, further research on biology teaching and learning should be carried out in Grade Eleven. Then, the research results will become generalizable to a wider population. According to time frame, this research was conducted for only seven topics. Further research should attempt to cover more topics from biology textbook. This study focused more on inquiry process skills and less on other inquiry approach such as field-based approach. Further research should focus on the latter.

Conclusion

The objective of this research is to investigate the applicability of IBL that can enhance students' inquiry process skills in teaching and learning high school biology. According to the research results, the experimental groups who received IBL improved inquiry process skills more than the control groups who did not in all schools. Therefore, it can be interpreted that IBL had a significant effect on students' biology achievement. Therefore, teachers should use IBL to develop the students' inquiry process skills.

Inquiry-based learning is not just teaching biology, but using biology to teach thinking. The implementing phase included inquiry process skills: questioning, observing, measuring, classifying, hypothesizing, experimenting, interpreting and communicating. Moreover, pretest and posttest were constructed on the basis of these inquiry process skills and the third domain of students' questionnaire was based on these inquiry process skills. According to the research findings, students with inquiry process skills could contribute to raise the biology achievement of the students. Therefore, it is suggested that inquiry-based learning should be applied to develop students' thinking skills in biology.

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