A STUDY OF THE CORRELATION BETWEEN STUDENTS' CRITICAL THINKING SKILLS AND THEIR MATHEMATICS ACHIEVEMENT AT THE MIDDLE SCHOOL LEVEL

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Abstract

The main purpose of this study is to study the correlation between students' critical thinking skills and their mathematics achievement at the middle school level. Especially, this study aims to study students' critical thinking skills in mathematics in terms of analysis, synthesis and evaluation level of Bloom's cognitive domain. A descriptive research design was used for this study. Four townships were randomly selected from four districts in Yangon Region. Twelve schools (eight high schools and four middle schools) were randomly selected from the four townships. The participants in this study included (600) Grade Eight students. As instruments, a test for critical thinking skills and a test for mathematics achievement were used. To obtain the reliability of these instruments, a pilot test was administered. The internal consistency (Cronbach's Alpha) of the test for students 'critical thinking skills was (.782) and of the test for students' mathematic achievement was (.807). In order to address the research questions, a descriptive statistics (percentage) and Pearson product-moment correlation were used. The percentage of low, moderate and high levels of students' critical thinking skills were 13.7% (N=82), 70.1% (N=421) and 16.2% (N=97) respectively. The percentage of low, moderate and high levels of students' mathematics achievement were 22.7% (N=136), 65.3% (N=392) and 12.0% (N=72) respectively. And also there was a positive correlation between students' critical thinking skills and their mathematics achievement ($r = .748$, $p < .01$).

Keywords: critical thinking, mathematics, achievement, cognitive domain, analysis, synthesis, evaluation

Introduction

Education is a lifelong process. Education is not teaching or learning of (3) R's - reading, writing and arithmetic. It consists of development of (4) H's – head, heart, hand and health. It also consists of knowledge, skills and attitudes. According to Dr. Radhakrishnan, education, to be complete, must be

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humane, it must include not only training of the intellect but also the refinement of the heart and the discipline of the spirit (Dhiman, 2007).

Nowadays, western world pays attention to the education of thinking, methods of thinking, and relying on the memories which attempt to change learning trend (Taghva et al., 2014). Especially, critical thinking has been one of the tools used in daily life to solve some problems because it involves logical reasoning, interpreting, analyzing and evaluating information to enable one take reliable and valid decisions. Mathematics and critical thinking cannot be separated from each other. Hence, teaching critical thinking in mathematics classes should be a goal of mathematics education. Critical thinking is both a process and an outcome. And also, critical thinking skill is one of the 21st century skills. So, it was very important to develop critical thinking skills in mathematics classrooms.

Statement of the Problem

Some teaching methods in Myanmar classrooms are based on the teacher-oriented methods and most of the time the learners only memorize their learned materials in short-term and then forget them easily. Indeed, the learners have not any active role and freedom in such a method. Most of the teachers use the textbooks only that involve low level thinking skills such as memorizing facts without thinking. Developing thinking capability is one of the main goals of mathematics education. It is very important to support the development of mathematical critical thinking skills in the classroom. However, today's mathematics classroom exactly cannot support students' critical thinking skills. Hence their mathematics achievement cannot be reached satisfied condition.

Purposes of the Study

The main purpose of this study is to study the correlation between students' critical thinking skills and their mathematics achievement at the middle school level. The specific purposes of this study are as follows.

- To study students' critical thinking skills in the selected schools.
- To investigate students' mathematics achievement in the selected schools.

- To find out whether there is a correlation between students' critical thinking skills and their mathematics achievement in learning mathematics.
- To give suggestions for improving critical thinking skills at the middle school level.

Research Questions

The present research will shed light on the following research questions.

(1) To what extent do students possess critical thinking skills in mathematics?

(2) To what extent do students possess mathematics achievement?

(3) Is there a relationship between students' critical thinking skills and their mathematics achievement?

Scope of the Study

This research has its own limitations. The first limitation is related to the fact that the participants of the study came from only Yangon Region. The participants in this study were (600) Grade Eight students from the twelve selected schools of the four districts (East, West, South, and North) in the academic year (2016-2017). Eight basic education high schools and four basic education middle schools were included in this study. The second limitation is that this study is only concerned with the correlation between students' critical thinking skills (analysis, synthesis and evaluation levels of thinking of Bloom's cognitive domain) and their mathematics achievement. The third limitation is the content area of the subject. The items of critical thinking skills test were constructed based on only content standards of National Council of Teachers of Mathematics (2000, cited in Wikipedia, n.d.) and sample items of North Carolina Department of Public Instruction (1999, cited in Thompson, n.d.).

Definition of Key Terms

Critical Thinking: It is defined as the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation,

experience, reflection, reasoning, or communication, as a guide to belief and action (Paul, 1992, cited in Vierra, 2014).

Analysis: It refers to the ability to break down material into its component parts so that its organizational structure may be understood (Jacobsen et al., 1989).

Synthesis: It is defined as the putting together of elements and parts so as to form a whole (Jacobsen et al., 1989).

Evaluation: It is concerned with the ability to judge the value of material for a given purpose (Jacobsen et al., 1989).

Achievement: It is the result of what an individual has learned from some educational experiences (Travers, 1970).

Significance of the Study

Efforts to develop the critical thinking skills of mathematics have become the main agenda in the curriculum of mathematics education worldwide (National Council of Teachers of Mathematics, 2000, cited in Firdaus et al., 2015). In the context of mathematical problem solving, Krulik and Rudnick (1995, cited in Firdaus et al., 2015) stated that critical thinking was analytical thinking and reflection that involved testing activities, questioning, connecting and evaluating all aspects of a situation or problem. Critical thinking skills are very important in mathematics learning because these skills can improve the quality of mathematics learning in better and meaningful.

Many educators argue that thinking skills can be learned and should be taught explicitly and students should be informed about the types of thinking skills taught to them. Research by Henningsen and Stein (1997, cited in Firdaus et al., 2015) showed that students' thinking skills can be developed if teachers create a classroom environment that supports the thinking activities. Teachers do not necessarily dominate and control the learning activities but should encourage students to take an active role and demonstrate good multilateral interaction between teacher and student or student to student interaction.

Critical thinking skills are necessary for students to succeed in their future. The skills of critical thinking should be applied and developed in core curriculum and teaching and learning process to produce students who have the quality of thinking critically when they become future leaders.

Mathematics teaching not only teaches mathematical content but also develop students' critical thinking skills that are necessary for students to solve various problems in school or in social life. Therefore, it is essential and necessary to develop students' critical thinking skills in all subjects, especially mathematics.

Theoretical Framework

Importance of Mathematics

It is necessary for every person to have a basic knowledge of mathematics to lead his daily life activities properly. The knowledge and skill in the fundamental process of mathematics can be achieved through the systematic study of this subject. Most of the occupations, by which the needs of people are fulfilled cannot run without the use of mathematics. The entire business and commercial system is the best on the knowledge of mathematics. It is helpful in the study of other sciences. It is an indispensable instrument for all physical researches. The progress of a nation depends upon the progress of mathematics. It is useful in budgeting. It is correlated with other subjects. So, mathematics occupies a prominent place in daily life.

Mathematics teachers need to use the best methodology to assist each learner to do well in the curriculum. Presently in the school curriculum as well as in the society the pupils need to develop knowledge and skills to perform well in achieving objectives. The teacher needs to study each pupil carefully to notice under which conditions maximum achievement is possible. Therefore, a teacher should not be a slave of only one method. A teacher should try to imbibe the good qualities of all the methods. A mathematics teacher will able to keep himself abreast of up-to-date knowledge of all methods and will exploit their advantages to the maximum. Students should be provided maximum opportunity of participation in the teaching and learning process. Therefore, not only mathematics is essential in everyday life but also the method the teacher used in the teaching of mathematics plays an important role in the 21st century education.

Importance of Critical Thinking Skills

Educators have long been aware of the importance of critical thinking skills as an outcome of student learning. More recently, the partnership for the 21st century skills has identified critical thinking as one of several learning and

innovation skills necessary to prepare students. (Lewis & Smith, 1993, cited in Lai, 2011).

Those working in the field of education have also participated in discussions about critical thinking. Benjamin Bloom's taxonomy for information processing skills is one of the most widely cited sources for educational practitioners when it comes to teaching and assessing higher order thinking skills. Bloom's taxonomy is hierarchical, with knowledge at the bottom and evaluation at the top. The three highest levels (analysis, synthesis, and evaluation) are frequently said to represent critical thinking (Kennedy et al., 1991, cited in Lai, 2011).

Critical thinking and problem solving are similar because they both encourage students to think about how they approach a problem or challenge and how to tackle the problem. Using the six steps to effective thinking and problem solving, or ''IDEALS'' (Facione, 2007, cited in Lai, 2011), the problem solver works through a case study or activity by responding to questions from the peer coach. The IDEALS are to identify, define, enumerate, analyze, list and self-correct.

I – Identify the problem: What is the real question we are facing?

D – Define the context: What are the facts that frame this problem?

E – Enumerate the choices: What are plausible options?

A – Analyze options: What is the best course of action?

L – List reasons explicitly: Why is this the best course of action?

S – Self correct: look at it again, what did we miss?

This problem solving technique guides students through the critical thinking process and utilizes learner collaboration. Haladyna (1997) expressed the complexity of thinking and learning dimensions by classifying four levels of mental processes (understanding, problem solving, critical thinking, and creativity) that can be applied to four types of content (facts, concepts, principles, and procedures). Applying a set of skills across dimensions of content fits well with the actual complex, recursive, and systemic processes of higher order thinking. Although his terminology often varies from other theorists', the territory is similar.

Haladyna's terms	**Gagné's terms**	**Bloom's terms**
facts	information	knowledge
concepts	concepts	comprehension
principles, procedures	rules	application
critical thinking	problem solving	synthesis and evaluation
creativity	no direct match	no direct match

The following procedure can be applied while solving a problem to develop critical thinking skills.

1. Identify the problem (which computational skill they need to use)
2. Conduct research (engaging with the information given)
3. Generate ideas (use previous knowledge to develop their understanding)
4. Develop possible solutions (apply your understanding)
5. Check solutions (have they used sound reasoning)

Bloom's Cognitive Education

Cognitive domain is the domain that deals with the recall and recognition of knowledge and the development of understandings and intellectual abilities and skills. Cognitive education is composed of the set of instructional methods that assist students in learning knowledge to be recalled or recognized, as well as developing students' understandings and intellectual abilities and skills. Bloom and his associates (1956, cited in Jacobsen et al., 1989) attempted and categorized the cognitive domain from simple concrete knowledge level toward the highest level of evaluation. North Carolina Department of Public Instruction (1999, cited in Thompson, n.d.) defined the following items of higher order thinking skills.

Analyzing

North Carolina Department of Public Instruction (1999, cited in Thompson, n.d.) defined analyzing as clarifying existing information by examining parts and relationships; identifying attributes and components; identifying relationships and patterns; identifying errors. The following items were labeled by North Carolina Department of Public Instruction as analyzing (higher order thinking).

(1) The formula to find the area of a circle is $A = \pi r^2$. What is the area of a circle if the diameter is 16 cm? (Use 3.14 for π)

(2) Which of the following is an algebraic expression for "twice the sum of a number and 5"?

Integrating (Synthesizing)

North Carolina Department of Public Instruction (1999, cited in Thompson, n.d.) defined integrating as combining information efficiently into a cohesive statement and changing existing knowledge structures to incorporate new information. The following items were labeled by North Carolina Department of Public Instruction as integrating or synthesizing (higher order thinking).

(1) The length of a house is 68 feet and the width is 24 feet. Find the area of the house.

(2) What is the sales tax on $10,200 automobile if the sales tax rate is 4%?

Evaluating

North Carolina Department of Public Instruction (1999, cited in Thompson, n.d.) defined evaluating as assessing the reasonableness and quality of ideas; creating standards for making judgments; confirming the accuracy of claims. The following items were labeled by North Carolina Department of Public Instruction as evaluating (higher order thinking).

(1) Which expression is equal to 144?

A. 72 + 72 B. 100 + 4 C.100 – 4 D. 225 - 64

(2) Using different data, two scientists each developed an equation for the same experiment. The equations were $y = \frac{2}{3}x - 4$ and $y = 3x + 10$. Which ordered pair is valid for both scientists?

A. (-6, -8) B. $(\frac{8}{3}, 2)$ C. $(-\frac{10}{3}, 0)$ D. (2 , 16)

In conclusion, the researcher investigated students' critical thinking skills in mathematics by using test based on these sample items of North Carolina Department of Public Instruction.

Research Method

Research Design

Quantitative research method was used in this study. The research design for this study was a descriptive research design.

Procedure

Firstly, the researcher defined a research problem. Then, the researcher sought out the literature through reading the resources. Moreover, the researcher studied the literature from the Internet sources. From the related literature, the researcher defined analysis, synthesis and evaluation levels of thinking skills to measure critical thinking skills according to Bloom's taxonomy of cognitive domain. After that research instruments were prepared, the instruments were validated through a pilot test with (50) Grade Eight students from B.E.H.S (1) East Dagon. After the pilot test, the sample schools and students for this study were selected. Tests were administered to all the participants of the twelve sample schools with the help of the headmaster/headmistress of those schools in January, 2017. After that, students' answer sheets for both critical thinking skills and mathematics achievement were scored manually based on the marking scheme. All the data were entered in the computer data file. Finally, the data were systematically analyzed by using the Statistical Package for the Social Science (SPSS 22).

Instruments

(i) Test for Students' Critical Thinking Skills

To study the students' critical thinking skills, a test for students' critical thinking skills was used. Under this studying, firstly, the table of specifications was prepared including eleven multiple choice items scoring (1) mark, three problems scoring (3) marks and six problems scoring (5) marks. Therefore, the total score was (50) marks. All items were constructed based on higher levels of Bloom's taxonomy of cognitive domain of North Carolina Department of Public Instruction (1999, cited in Thompson, n.d.). First, four multiple choice items, one problem for (3) marks and two problems for (5) marks were based on analysis level of thinking. Second, three multiple choice items, one problem for (3) marks and two problems for (5) marks were based on synthesis level of thinking. Third, four multiple choice items, one problem for (3) marks and two problems for (5) marks were

based on evaluation level of thinking. The content areas of this test were based on content standards of National Council of Teachers of Mathematics (2000, cited in Wikipedia, n.d.).

(ii) Test for Students' Mathematics Achievement

In order to measure the students' mathematics achievement, a test for students' mathematics achievement was constructed. It was based on the content areas of Grade Eight mathematics textbooks prescribed by the Department of Education, Basic Education Curriculum, Syllabus and Textbook Committee, 2013-2014 academic year. The table of specifications was prepared including ten multiple choice items scoring (1) mark, five problems scoring (3) marks and five problems scoring (5) marks. Therefore, the total score was (50) marks. This test includes (16) chapters: (13) chapters from mathematics textbook volume I and (3) chapters from mathematics textbook volume II.

Population and Sample Size

All the participants in the sample were Grade Eight students. This study was conducted in Yangon Region. There are four districts in Yangon Region. One township from each district was randomly selected for this study. The sample schools for the study were selected by using a stratified random sampling technique. Two high schools and one middle school from each township were selected as the sample. Therefore, twelve schools (eight high schools and four middle schools) were included in this study. Fifty Grade Eight students from each selected school were selected as the subjects by an equal-sized random sampling technique. The number of participants was (600).

Data Analysis

The descriptive analysis techniques were used to calculate means, standard deviation and percentage. Moreover, Pearson product-moment correlation was used to describe the correlation between students' critical thinking skills and their mathematics achievement.

Research Findings

Finding of Students' Critical Thinking Skills

In order to find out the students' critical thinking skills, a descriptive statistics (mean, standard deviation, and percentage) were used. The mean and the standard deviation by all the participants were (14.57) and (8.779) respectively. By using standard deviation, students who possessed marks above (23) were defined as high achieving students in critical thinking skills. Students who possessed marks from (6) to (23) were defined as moderate achieving students in critical thinking skills. And then students who possessed marks under (6) were defined as low achieving students in critical thinking skills. Table (1) described the percentage of students who possessed low, moderate and high levels of critical thinking skills.

Table 1 Students' Critical Thinking Skills Level

Students' Critical Thinking Skills Level	Score	No. of Student	Percentage (%)
Low	0-5	82	13.70%
Moderate	6-23	421	70.10%
High	24-50	97	16.20%
Total		**600**	**100%**

Finding of Students' Mathematics Achievement in the Selected Schools

In order to examine the students' mathematics achievement, a descriptive statistics (mean, standard deviation, and percentage) were used. The mean and the standard deviation by all the participants were (20.81) and (10.824) respectively. By using standard deviation, students who possessed marks above (32) were defined as high achieving students in mathematics. Students who possessed marks from (10) to (32) were defined as moderate achieving students in mathematics. And then students who possessed marks under (10) were defined as low achieving students in mathematics. Table (2)

classified the percentage of students who possessed low, moderate and high levels of mathematics achievement.

Table 2: Students' Mathematics Achievement Level

Students' Mathematics Achievement Level	Score	No. of Student	Percentage (%)
Low	0-9	136	22.70%
Moderate	10-32	392	65.30%
High	33-50	72	12.00%
Total		**600**	**100%**

Finding of the Correlations between Students' Critical Thinking Skills and their Mathematics Achievement in the Selected Schools

To investigate the correlation between students' critical thinking skills and their mathematics achievement, Pearson product-moment correlation was used. Firstly, the correlations between sub-components of students' critical thinking skills and their mathematics achievement were presented. According to Gay and Airasian (2003), correlation coefficient below plus or minus (.35) was interpreted as low or no relation, correlation coefficient between plus or minus (.35) and (.65) was interpreted as moderate relation and correlation coefficient higher than plus or minus (.65) was interpreted as high relation.

Table 3: Correlations between Students' Critical Thinking Skills (Analysis, Synthesis and Evaluation) and their Mathematics Achievement in the Selected Schools

Correlation		
Level of Critical Thinking Skill		**Students' Mathematics Achievement**
Analysis Level of Thinking	Pearson Correlation	**.631****
	Sig. (2-tailed)	.000
	N	600
	Pearson Correlation	**.548****

Synthesis Level of Thinking	Sig. (2-tailed)	.000
	N	600
Evaluation Level of Thinking	Pearson Correlation	**.655****
	Sig. (2-tailed)	.000
	N	600
Critical Thinking Skills	Pearson Correlation	**.748****
	Sig. (2-tailed)	.000
	N	600

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

Discussion, Suggestions and Conclusion

Discussion

Understanding and fostering the ability to help students think critically is essential to their educational success. Duron, Limback, and Waugh (2006) defined critical thinking as the ability to analyze and evaluate information. In teaching and learning mathematics in schools, critical thinking needs to be integrated and emphasized in the curriculum so that students can learn the skills and apply it to improve their performance and reasoning ability. Assessment of critical thinking skills is an educational priority. With this view, this study seeks to address this demand by investigating the relationship between critical thinking skills and mathematics achievement.

The percentage of students who possessed low, moderate and high levels of critical thinking skills were 13.7% (N=82), 70.1% (N=421) and 16.2% (N=97) respectively. So, these findings revealed the answer to the first research question: To what extent do students possess mathematics achievement?

The percentage of students who possessed low, moderate and high levels of mathematics achievement were 22.7% (N=136), 65.3% (N=392) and 12% (N=72) respectively. So, these findings revealed the answer to the second research question: To what extent do students possess critical thinking skills in mathematics?

The correlation between students' critical thinking skills and their mathematics achievement was (r (10) = .748, $p < .01$). This result showed that the direction of correlation was positive. It was a high correlation. It is pointed out that if the students' critical thinking skills was high, their mathematics

achievement was also high or if the students' critical thinking skills was low, their mathematics achievement was also low. So, this finding revealed the answer to the third research question: Is there a relationship between students' critical thinking skills and their mathematics achievement?

According to the results of the research, a generalization can be drawn that students' critical thinking skills significantly influenced the students' mathematics achievement. Therefore, it can be realized that it is crucial to foster students' critical thinking skills for improving their mathematics achievement in the middle schools.

Suggestions

Instruction which promotes critical thinking skills can foster academic achievement gains. These skills are necessary for everyone to have in rapidly changing, technologically oriented world. So, everyone should develop critical thinking skills in order to face the challenges of the 21st century. Teachers' role, students' role and classroom activities for improving higher levels of Bloom's cognitive domain (analysis, synthesis, and evaluation), instructional strategies, assessment for promoting critical thinking skills and suggestions for further study are given as suggestions.

(i) Teachers' role, students' role and classroom activities for improving higher levels of Bloom's cognitive domain (analysis, synthesis, and evaluation): In order to develop analysis level of thinking of students, the students should discuss found knowledge, dissect information into parts and understand relationships and classification of information. And also the teachers should probe students, act as resource and guide students in direction of outcomes. Moreover, in order to improve students' analysis level of thinking in all subjects, the teachers should carry out such classroom activities as presenting information in graph, presenting survey results, planning a diagram, developing questionnaire, developing a mind map, stating attributes of issues, developing outline of process and developing chart for plan of action.

In order to develop synthesis level of thinking of students, the students should generalize from facts, predict and draw conclusions and use old ideas to create new ones. And also the teachers should extend student thinking and evaluate through non-traditional ways. Moreover, in order to improve students' synthesis level of thinking in all subjects, the teachers should carry out such classroom activities as composing a song, developing a mural,

writing a puppet show, skit, developing an advertisement, presenting a solution for change, discovering own invention, designing a newspaper and writing a story.

In order to develop evaluation level of thinking of students, the students should judge outcomes, disputes thoughts and ideas and form opinions. And also the teachers should lay the criteria and act as facilitator. Moreover, in order to improve students' evaluation level of thinking in all subjects, the teachers should carry out such classroom activities as participating on panel, giving a recommendation, conducting a mock trial, evaluating project, stating decisions, participating in debate, arriving at group conclusion, developing a rating scale, backing the opinions, presenting and writing and editorial.

(ii) Instructional strategies: Higher order thinking skills require students to manipulate information and ideas in ways that transform their meaning and implications. This transformation occurs when students combine facts and ideas in order to synthesize, generalize, explain, hypothesize, or arrive at some conclusion. Effectiveness in planning and teaching can improve student achievement in mathematics. The use of higher order skills from Bloom's taxonomy can serve as a guide to use good pedagogy in the classroom. Once teachers have developed the skills and understanding, these elements can be integrated into the daily activity of the classroom. The use of Bloom's taxonomy and knowing the composition of the class that makes teaching more conscious and purposeful.

Questioning should be used purposefully to achieve well-defined goals. Typically a teacher should vary the level of questions within a single lesson. Usually questions at the lower levels are appropriate for evaluating students' preparation and comprehension, diagnosing students' strengths and weaknesses and reviewing or summarizing content. Questions at higher levels of the taxonomy are usually most appropriate for encouraging students to think more deeply and critically, problem solving, encouraging discussions and stimulating students to seek information on their own. The teacher should plan a lesson, which includes a variety of activities and questions, forcing students to think and function at each level of the Bloom's taxonomy. Mathematics teachers should prepare questions and activities related to all levels of Bloom's taxonomy directly related to the content of study.

(iii) Assessment for promoting critical thinking skills: Open-ended problem types may be more appropriate than traditional multiple-choice formats. For

this reason, the researcher studied critical thinking skills using a test of mixed item format, both multiple-choice and open-ended. Teachers should adopt different assessment methods, such as exercises that allow students to self-construct answers, assignments that facilitate the practice of strategic use of thinking skills in everyday contexts, and when adopting multiple-choice exercises, follow-up questions should be given to probe students' underlying reasoning.

(iv) Suggestions for further study: No study is perfect in a single effort. This study was dealt with the students' critical thinking skills such as analysis, synthesis and evaluation from Bloom's cognitive domain. Therefore, further studies should be conducted with other thinking skills such as inference, inductive reasoning, deductive reasoning, interpretation and so on.

Conclusion

Education is important because it gives people the baseline skills to survive as adults in the world. These skills include basic literacy and numeracy, as well as the ability to communicate, complete tasks and work with others. Among the skills, thinking skills are essential in solving problems of mathematics. Without thinking, students cannot require real achievement in mathematics. They cannot solve new problems. Thus the teachers should teach mathematics to their students with thinking and not with rote memorization

If a critically thoughtful approach helps students better understand what they are learning, it makes sense to invite students to make decisions about every aspect of mathematics, including selecting strategies for building number sense and mastery of basic facts, deciding how to approach a problem for which they have no ready-made solution or procedure, choosing the most appropriate way to represent a mathematical situation, monitoring their problem solving progress and adjusting as necessary, analyzing their own responses, communicating their mathematical ideas effectively and connecting mathematics with their own lives and the wider world.

According to the literature, critical thinking is important in life. It can lead to the development of students' judgment, evaluation and problem solving abilities. Learning critical thinking skills can also enhance students' academic performance. Students with critical thinking skills become more independent, self-directed learners rather than relying on teachers and others. If the students have the ability to analyze, synthesize and evaluate critically,

then their mathematics achievement will be high. So, every teacher should create a learning environment in which students think critically and creatively rather than memorizing facts. Teachers should develop interesting classroom activities to enhance thinking skills of students. Although this study cannot fulfill all the aims of teaching and learning mathematics in the middle schools, it can be a support for teachers to foster the middle school students' critical thinking skills in Myanmar.

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Appendix A

(Test for Students' Critical Thinking Skills)

t|rwef; (Grade Eight) ausmif;om;^olrsm;\ ocFsmbmom&yfqkdif&m aMumif;usdK;qufpyf pOf;pm;awG;ac:EdkifaompGrf;&nf ppfaq;vTm

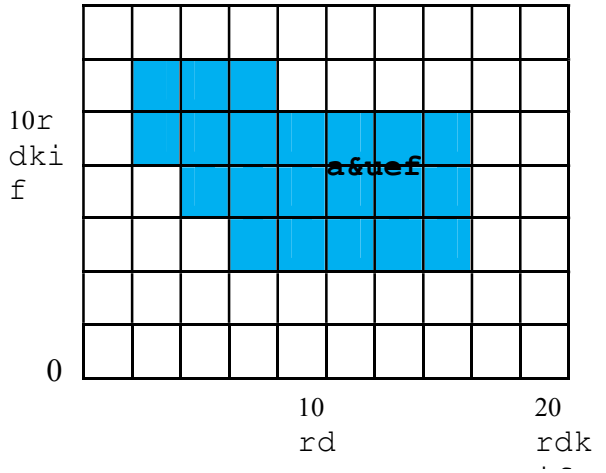
2017 ckESpf cGifhhjyKcsdef (1;30) em&D

nTefMum;csuf/ / atmufygar;cGef;rsm; tm;vHk;udkajzqdkyg/

tydkif; (u)

cGJjcrf;pdwfjzmEdkifrI (Analysis)

1.



yHkygay;xm;csufrsm;t& a&uef\ pkpkaygif; ywfvnftvsm;udk a&G;cs,fyg/

A. 22 rdkif B. 44 rdkif C. 48 rdkif D. 56 rdkif E. 84 rdkif

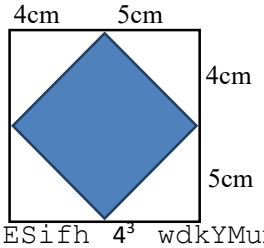
2. atmufygazmfjycsufrsm;teuf rSefuefonfhazmfjycsufudk a&G;cs,fyg/

A. $3\frac{2}{3} < 3\frac{1}{3} < 2\frac{2}{3}$, B. $3\frac{2}{3} < 2\frac{2}{3} < 3\frac{1}{3}$, C. $3\frac{1}{3} > 2\frac{2}{3} > 3\frac{2}{3}$

D. $3\frac{2}{3} > 3\frac{1}{3} > 2\frac{2}{3}$, E. $3\frac{1}{3} < 3\frac{2}{3} < 2\frac{2}{3}$

3. ay;xm;aomyHkwGif jc,frIef;xm;aom pwk&ef;\ {&d,mudk a&G;cs,fyg/

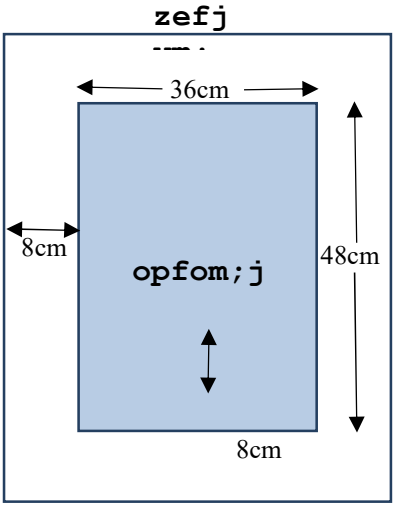
A. $20cm^2$ B. $36cm^2$ C. $41cm^2$ D. $61cm^2$ E. $81cm^2$



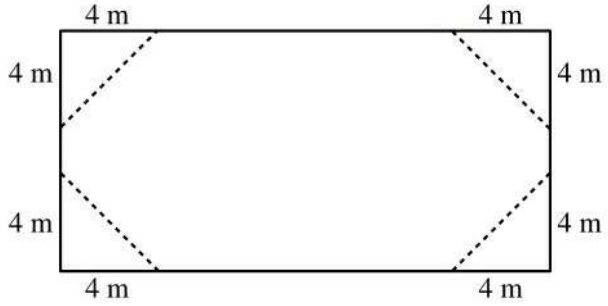
4. 4^2 ESifh 4^3 wdkYMum;wGif&Sdaom tjynfhudef; ta&twGuf pkpkaygif;udkazmfjyyg/

A. 45 B. 46 C. 47 D. 48 E. 49

5. pm;yGJwpfvHk;\ rsufESmjyifudk zefjym;jzifhjyKvkyfxm;\/ twGif;ydkif;udk opfom;jym;jzifh jyKvkyfxm;\/ zefjym;onf opfom;jym;xuf 8cm ywfvnfydkus,faomf zefjym;\ pkpkaygif;ywfvnftem;udk&Smyg/



6. axmifhrSefpwk*Hwpfck\ tvsm;onf 20m &Snfí teHonf 10m &Snf\/ axmifhrSefpwk*HrS Mwd*Hav;ckudk z,fvdkufvSsif usefaomtydkif;\ {&d,mudk&Smyg/



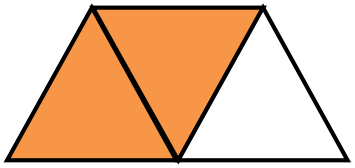
7. armifarmifonf urf;ajcrS tdrfodkY oJ $1\frac{1}{3}$ aygif o,fvmonf/ xkdoJrsm;udk armifarmifonf ykvif;rsm;xJodkY xnfh\/ ykvif;wpfvHk;vQif oJ $\frac{2}{9}$ aygifom qHh\/ xdktcg armifarmifhtwGuf oJtm;vHk;xnfh&ef ykvif;pkpkaygif; rnfrSsvdktyfoenf;/

tydkif; (c)

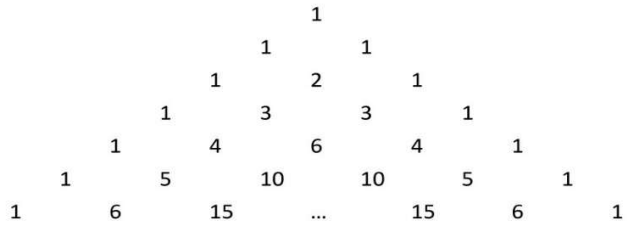
aygif;pyfpkpnf;EdkifrI (Synthesis)

1. ay;xm;aom MwmyDZD,rfyHkudk wlnDaom Mwd*H oHk;cktjzpf tydkif;ydkif;xm;ygonf/ jc,frIef;xm;aom tem;jydKif pwk*H\ {&d,mrSm 16cm^2 jzpfcJhvQif MwmyDZD,rf\ {&d,mudk wGufyg/

A. 8cm^2 B. 24cm^2 C. 32cm^2 D. 48cm^2 E. 56cm^2



2. atmufazmfjyyg udef;pOfwGif vkdtyfaeaomudef;udk cefYrSef;ajzqdkyg/



A. 5 B. 20 C. 21 D. 10 E. 425

3. $\frac{1}{2}+\frac{1}{4}=\frac{3}{4}$

$\frac{1}{2}+\frac{1}{4}+\frac{1}{8}=\frac{7}{8}$

$\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}=\frac{15}{16}$

$\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+\frac{1}{32}=\frac{31}{32}$ jzpfcJhvQif

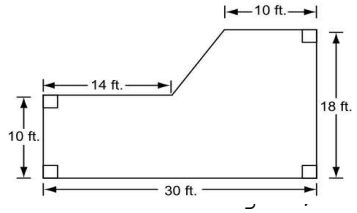
$\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+\ldots+\frac{1}{1024}=?$

xdkudef;wef;\ aygif;v'fudk cefYrSef;ajzqdkyg/

A. $\frac{1001}{1024}$ B. $\frac{1010}{1024}$ C. $\frac{1023}{1024}$ D. $\frac{1025}{1024}$ E. $\frac{1022}{1024}$

4. jrjronf ol\acG;udk aeYpOf tpm 8 atmifpauGs;onf/ &ufaygif; 40 Mumaomf jrjr\ acG;onf tpmpkpkaygif; aygif rnfrQ pm;cJhoenf;/

5. ay;xm;aomyHk\ {&d,mudk wGufyg/ (ft. = ay)



6. vl 4 a,m aumfzDrIefYyHk;rsm; 0,f,l\/ vlwpfa,mufvQif wpfyHk;om

0,f,lcGifh&Sdonf/ odkUaomf wpfyHk;pDwGif yg0ifaom aumfzDrIefUatmifpESifh aps;EIef;rsm;onf

rwlnDMuay/ xdktcg rnfol\ aumfzDrIefYyHk;onf aps;EIef;toufomqHk; jzpfrnfenf;/

	aumfzDyHk;aps;EIef;	**yg0ifaomatmifp**
yxrvl	3.84 a':vm	24 atmifp
''kwd,vl	3.90 a':vm	30 atmifp
wwd,vl	4.48 a':vm	32 atmifp
pwkw¬vl	4.25 a':vm	25 atmifp

tydkif; (*)

tuJjzwfwGufcsufEdkifrI (Evaluation)

1. x = 3, y = 5 jzpfcJhvQif $3x^2 - 2y$ \wefzdk;onf $2x^2 - 3y$ \wefzdk;xuf rnfrQydkoenf;/

A. 4 B. 14 C. 16 D. 20 E. 50

2. ay;xm;aomZ,m;wGif x ESifh y wdkU\ qufoG,fcsufudk toHk;jyKí vdktyfaom y \wefzdk;udk azmfjyyg/

x	y
1	3
1.5	4.5
2	6
2.5	
3	9
3.5	10.5

A. 5 B. 6.5 C. 7 D. 7.5 E. 8

3. $(11x + 2) + (6x + 4) + (x + 5) > 90$

¤if;rS x \wefzdk;udk azmfjyyg/

A. $x > \frac{79}{18}$

B. $x > \frac{79}{17}$

C. $x > \frac{101}{18}$

D. $x > \frac{101}{17}$

E. $x > \frac{78}{17}$

4. em&DwpfvHk;wGif em&DvufwHwpfckom&Sd\/ xdkem&DvufwHonf 4 em&DESifh 5 em&DMum; $\frac{2}{5}$ ae&modkY

a&mufaeaomf em&DnTefjyaeaom tcsdefudkazmfjyyg/

A. 04:10 B. 04:20 C. 04:22 D. 04:24 E. 04:26

5. ay;xm;aomZ,m;udktoHk;jyKí vkdtyfaomudef;ESpfvHk;\ wefzdk;udk azmfjyyg/ x ESifh y wdkU\

qufoG,fcsufudk azmfjyyg/ (Z,m;udkjyeful;í jznfhyg)

x	y
0.5	2
1	1
2	0.5
4	0.25
5	
10	

6. ausmfausmfonf 20% aps;avQmhxm;aom wD&Syfwpfxnfudk 15%avQmhay;aom ol\ ulyGefuwfjzifh

0,fcJh\/ wD&Syf\ rlvwefzdk;onf 37000usyfjzpfaomf ausmfausmfonf wD&Syfudk rnfhonfhaps;EIef;jzifh

0,fcJhoenf;/

7. udef;pOf 9, 10, 13, 18, … rS 13 Mudrfajrmuf udef;udk azmfjyyg/

udef;pOf $1, \frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \ldots$ rS 8 Mudrfajrmuff udef;udk azmfjyyg/

udef;pOf 1×2, 2×3, 3×4, 4×5, … rS n Mudrfajrmufudef;udk azmfjyyg/

udef;pOf 1, 0.1, 0.01, 0.001, … rS 7 Mudrfajrmuf udef;udk azmfjyyg/

udef;pOf 3, 9, 27, 81, … rS n Mudrfajrmufudef;udk azmfjyyg/

Appendix B

(Test for Students' Mathematics Achievement)

t|rwef;(Grade Eight) ausmif;om;^olrsm;
ocFsmbmom&yfqkdif&m wwfajrmufrIppfaq;vTm

2017 ckESpf
cGifhhjyKcsdef (1;30) em&D

nTefMum;csuf/ atmufygar;cGef;rsm;
tm;vHk;udkajzqdkyg/

tydkif; (u)

atmufygwkdYrS tajzrSefudk a&G;cs,fyg/

1. $\sqrt{2} - \frac{2}{\sqrt{2}}$ udk&Sif;vQif atmufygwdkUteuf rnfonfhudef;ESifh wlnDoenf;/

A. 0 B. $\sqrt{2}$ C. $\frac{1}{\sqrt{2}}$ D. $-\frac{1}{\sqrt{2}}$

2. V = $\frac{4}{3}\pi r^3$ yHkaoenf;rS π udk &Sm&ef yHkaoenf;rSm atmufygwdkUteufrS rnfonfhtcsuf jzpfoenf;/

A. $\frac{3r^2}{4V}$ B. $\frac{4V}{3r^3}$ C. $\frac{4r^3}{3V}$ D. $\frac{3V}{4r^3}$

3. $2x + 3y = 16$

$x + 3y = 11$ jzpfvQif $x + 2y$ \ wefzdk;udk&Smyg/

A. 12 B. 9 C. 6 D. 3

4. x 0if&dk;ay:&Sd trSwfwkdif;\y udkMo'dedwf wefzdk; udk&Smyg/

A. 1 B. -1 C. 2 D. 0

5. $1\times2\times3$, $2\times3\times4$, $3\times4\times5$, … udef;pOf \ pwkw¬ajrmufudef; udk&Smyg/

A. $3\times5\times7$ B. $4\times5\times6$ C. $5\times6\times7$ D. $2\times4\times6$

6. tajcoHk;jzif 102 + 212 udk&Sif;vQif &&Sdrnfhtajzrsefudka&G;cs,fyg/

A. 321 B. 1021 C. 1201 D. 1102

7. trSm;cefYrSef;&mwGif tvsm; 3.6 cm &Sd rsOf;wpfaMumif;twGuf ti,fqHk;rlwnfudef;onf atmufygwdkUteuf rnfonfhtvsm; jzpfoenf;/

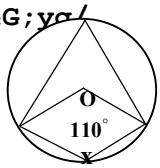
A. 1 cm B. 0.01 cm C. 0.1 cm D. 0.001cm

8. Mwd*Hwpfck\ tem;wpfzuf\ tv,frSwfudkjzwfí tem;wpfzufESifh jydKifatmif qGJaomrsOf;onf usefwwd,tem;udk rnfodkYydkif;jzwfoenf;/

A. xuf0uf B. av;yHkwpfyHk C. oHk;yHkESpfyHk D. oHk;yHkwpfyHk

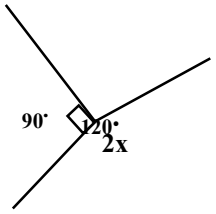
9. **yHkygay;xm;csufrsm;t&** x**wefzdk;udka&G;yg/**

A. 20° B. 70° C. 110° D. 125°



10. yHkygay;xm;csuft& x onf atmufygwdkUteuf rnfonfhwefzdk;ESifh nDoenf;/

A. 5° B. 80° C. 55° D. 45°



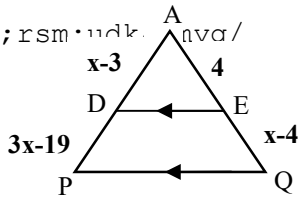
tydkif; (c)

1. $3^{2x-1} \times 3^{4x+8} = (\frac{1}{27})^{2x-5}$ jzpfvQif x udk&Smyg/

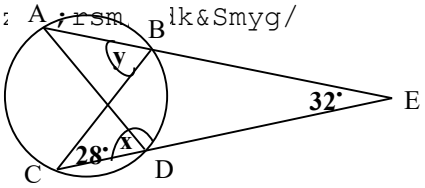
2. ydkvDEdkrD,,f $\frac{83}{7}y+\frac{18}{5}y^2-\frac{6}{7}y^3$ udk ydkvDEdkrD,,f $\frac{6}{5}y^2+\frac{1}{7}y^3-\frac{2}{7}y^5$ rS Ekwfyg/

3. $\frac{x^2+9x+14}{x^2-3x} \times \frac{2x^2+2x}{x^2+6x-7} \div \frac{x}{x-3}$ udk&Sif;yg/

4. yHkwGif DE // PQ jzpf\/ x \ wefzdk;rsm;udk;cnvg/



5. yHkwGif x ESifh y wkdU\ wef; A ;rsm;udk&Smyg/



tydkif; (*)

1. axmifhrSefpwk*Hwpfck\ Murf;jyif{&d,monf 144 pwk&ef;ay jzpf\/ ¤if;tcef;\ tvsm;onf
teHxuf 10 ayydkí &Snfaomf tcef;\ tvsm;ESifh teHudk&Smyg/

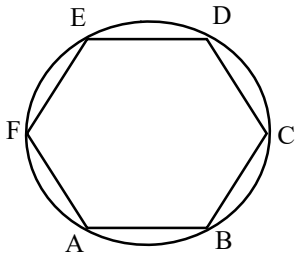
2. pufavSwpfpif;onf acsmif;wpfcktwGif; ckwfarmif;&m a&qefwGif 5 rdkifc&D;armif;Edkifonfh tcsdeftwGif; a&pkefü 9 rdkifc&D;armif;Edkif\/ xdkacsmif;\ a&pD;EIef;rSm wpfem&D 2 rkdifjzpfvQif a&jidrfü xdkpufavSonf wpfem&D rkdifrnfrQ ckwfarmif;Edkifoenf;/

3. $A = \{2, 3, 5, 7, 9\}$, $B = \{2, 3, 5, 4, 5\}$ ESifh $C = \{2, 4, 6, 7, 8, 9\}$ jzpfvQiff atmufygwdkUudk&Smyg/

(i) $A \cap B$ (ii) $B \cap C$ (iii) $(A \cap B) \cap C$ (iv) $A \cap (B \cap C)$
(v) $(A \cap B) \cap C = A \cap (B \cap C)$ jzpfygovm;/

4. ay;csuf ABCDEF onf puf0dkif;wGif;us q|*H jzpfonf/

oufaojy&ef $\angle FAB + \angle BCD + \angle DEF = 360°$



5. ay;xm;aomMwmyDZD,rfyHkrS BD, AC ESifh CD wdkUudk&Smyg/