AN INTERVENTION BASED ANALYSIS OF REASONING SKILLS AMONG PRE-SERVICE TEACHERS FROM UNIVERSITIES OF EDUCATION IN MYANMAR

Yar Zar Chit[1], Khin Pyone Yi[2], Khin Thuza Saw[3]

Abstract

The main aim of this study was to investigate the reasoning skills of pre-service teachers from Universities of Education in Myanmar based on an intervention practice. As the participants for this study, 1626 pre-service teachers from Universities of Education were selected by stratified random sampling technique. Sequential explanatory design was mainly used. This study was based on Evans and Over's (1996) dual-process theory. A Reasoning Skills Test (RST) was mainly used to examine the participants' reasoning skills. Therefore, firstly, an optimal reasoning test was developed by using Item Response Test Theory (IRT). Based on the quantitative results, an intervention practice namely argument mapping technique was conducted to improve pre-service teachers' reasoning skills. Therefore, an intervention protocol required for intervention practice was also constructed in accordance with Myanmar culture. The results pointed that the reasoning skills of pre-service teachers after intervention were significantly higher than before intervention. Therefore, this study highlighted the reasoning skills can be trained and improved. Consequently, this study gave a reasoning skill test and an intervention technique suitable for Myanmar pre-service teachers. It is hoped that the contributions of this study can be a support for upgrading teacher education in Myanmar.

Keywords: Reasoning skills, item response theory, optimal test, intervention practice

Introduction

The powers of thinking and reasoning may thus be considered to be the essential tools for the welfare and meaningful existence of the individual as well as society. The reason is that a chief characteristic which can distinguish human beings from other species including the higher animals is cognitive ability including thinking, reasoning, problem solving and other aspects based on human brain functions.

Also, humans have used reasoning to work out what they should believe and how they should act since the earliest stages of human evolution. However, humans started to reflect on the reasoning process itself particularly in academic contexts. Johnson-Laird and Shafir (1993) indicated that reasoning and decision making are high level of thinking skills which have been investigated for the last thirty years. Kirwin (1995) concluded that reasoning is the cognitive process of looking for reasons for beliefs, conclusions, actions or feelings. Therefore, humans have the ability to engage in reasoning about their own reasoning.

Moreover, Professor Dr. Khin Zaw (2001) pointed the fact that man has reason and imagination leads not only to the necessity for having a sense of his own identity, but also for orienting himself in the world intellectually. Additionally, he differentiated reason from intelligence. Reason is man's faculty for grasping the world by thought, in contradiction to intelligence, which is man's ability to manipulate the world with the help of thought. Reason is man's instrument for arriving at the truth; but intelligence is his instrument for manipulating the world more successfully; the former is essentially human, the latter belongs to the animal part of man.

[1] Dr, Assistant Lecturer, Department of Educational Psychology, Sagaing University of Education
[2] Dr, Retired Professor and Head, Department of Educational Psychology, Yangon University of Education
[3] Dr, Retired Principal, Thingangyun Education College

Likewise, reasoning skills are instruments for making decisions using specific cognitive skills, assessing skills and thinking systematically or abstractly (Fischhoff, Crowell, & Kipke, 1999). So, reasoning plays a significant role in one's environment. It controls not only one's cognitive activities but may also influence the total behavior and personality. Reasoning may thus be termed as highly specialized thinking which helps an individual to explore mentally the cause-and-effect relationship of an event or solution of a problem by adopting some well-organized systematic steps based on previous experiences combined with present observation (Mangal, 2012).

At the present time, in the modern technological world, communications are sophisticated, and people have a variety of information to stimulate and inform their thinking. However, it is not just right information that is distributed in society. False and misleading information is also spread out to people too. People have to be able to analyze, discriminate and make good decisions on the basis of sound reasons. Education therefore has a crucial role to play in developing that ability.

In ancient years of Myanmar education, the technology used in teaching-learning process was rote learning. However, today's education system is directing to a system based on student's cognitive skills such as creative thinking, critical thinking, reasoning skills and problem solving skills. Therefore, the teachers and also pre-service teachers who will have to take the responsibility for students to be improved the cognitive skills should keep these skills themselves. Accordingly, these factors become the reasons for the researcher to develop a reasoning skill test as well as to explore a technique for improving the reasoning skills of pre-service teachers from Universities of Education in Myanmar.

Purpose of the Study: The main purpose of the study is to investigate the reasoning skills of pre-service teachers from Universities of Education in Myanmar based on an intervention practice. The specific objectives are as follows:

1. To develop a reasoning skill test by using Item Response Theory (IRT)
2. To examine the reasoning skills of pre-service teachers by using the optimal test
3. To compare the differences of pre-service teachers' reasoning skills according to gender and institution
4. To explore a technique to improve the pre-service teachers' reasoning skills

Related Literature Review

Early formulations of behaviorism regarded human life as a "black box." These behaviorists viewed *input* or *stimuli* as entering the "box" at one end and coming out the other end as *responses*. What was inside the box did not concern them. But over the past 50 years, psychologists have become increasingly interested in what goes on inside the box. They term these internal factors "cognition"— acts or processes of knowing. Cognition involves how humans go about representing, organizing, treating, and transforming information as they devise their behaviors. It encompasses such phenomena as sensation, perception, imagery, retention, recall, problem solving, reasoning, and thinking. Cognitive psychologists are especially interested in the cognitive structures and processes that allow a person to mentally represent events that transpire in the environment (Galotti, 2004).

Evans and Over's Dual-Process Theory: The psychological origins of the dualist distinction between rational and irrational thinking can be traced back to James (1890) and Freud

(1900). Both claimed that reasoning takes the form of two different modes of thought. James regarded reasoning as an experiential associative type of thinking, as well as a separate analytical deliberate mode (as cited in Osman, 2004).

This theory divided reasoning into two systems. System 1, implicit or tacit process, which is essentially pragmatic, is based on prior experiences, beliefs, and background knowledge and achieves goals reliably and efficiently without necessarily accompanying awareness. System 2 is explicit, intentional, sequential, controllable, and makes high demands of working memory. System 2 does not typically operate according to normative logical conventions, but it is capable of achieving solutions to logical problems as well as a range of problem types.

On the other hand, reasoning involves both conscious (or explicit) and unconscious (or tacit) processes. For example, inductive reasoning largely depends on the retrieval and unconscious evaluation of world knowledge, whereas deductive reasoning depends on rule-based or conscious formal procedures.

In fact, reasoning refers to the process of drawing conclusions or inferences from information. Reasoning always requires going beyond the information that is given (Bruner, 1957). In logic, an inference is called *deductive* if the truth of the initial information (or premises) guarantees the truth of the conclusion. The inference is called *inductive* if the truth of the premises makes the conclusion probable but not certain. Many researchers have found that performance on deductive and inductive tests is strongly related (Wilhelm, 2005).

Although there are several kinds of inductive reasoning, this research will focus on analogical and numerical reasoning.

Analogical Reasoning: The ability to reason analogically involves the ability to make judgments or predictions about unfamiliar problems on the basis of perceived similarities and relationships with familiar problems. This form of inferential reasoning also serves a variety of different functions ranging from drawing people's attention to already known relations to the reorganization and development of existing knowledge (Deloache, Miller, & Pierroutsakos, 1998).

Numerical Reasoning: It includes the ability to solve problems and arrive at answers, i.e., solution in a logical way and making generalization (Fatima, 2008). Numerical reasoning is about using numerical data to make reasoned decisions and solve problem. It relies on the ability to recognize how to go about solving a numerical problem, understanding the relationships between numbers, prior to completing the mathematical calculation required (Savill, 2011).

Like inductive reasoning, there are several kinds in deductive reasoning. However, this research will focus on analytical and abstract reasoning.

Analytical Reasoning: Analytic reasoning represents judgments made upon statements that are based on the virtue of the statement's own content. Analytical skill is the ability to visualize, articulate, conceptualize or solve both complex and uncomplicated problems by making decisions that are sensible given the available information. Such skills include demonstration of the ability to apply logical thinking to breaking complex problems into their component parts (Kant-Studien, 1987).

Abstract Reasoning: Abstract Reasoning is also known as fluid intelligence (Cattell, 1963) or analytic intelligence. Fluid intelligence is reasoning ability in its most abstract and

purest form. It is the ability to analyze novel problems, identify the patterns and relationships that underpin these problems and extrapolate from this using logic (Carpenter, Just, and Shell, 1990).

Design and Procedure

Sampling. As the participants of this study, there were 1626 pre-service teachers from first year to fifth year: male (n=746) and female (n=880) in 2017-2018 Academic Year. The participants for the study were chosen from Universities of Education in Myanmar: Yangon University of Education, Sagaing University of Education and University for the Development of National Races of the Union. A stratified random sampling technique was used.

Research Method. Sequential explanatory design from quantitative and qualitative mixed method approaches was taken as the primary design of this study. In the first part of this study, survey method was used. As the second part, an intervention based analysis based on the experimental method was also used.

Pilot Testing on Reasoning Skill Test. There were four subtests in reasoning skill test and each subtest comprised of 23 items. The test items were multiple-choice items. The responses in all test items will be scored 1 if answered correctly and 0 if answered incorrectly. Therefore, the total score for the test is 92. The test was administered to a sample of 220 pre-service teachers (from first year to fifth year) in Sagaing University of Education. After carrying out the item analysis based on an IRT parameter estimation procedure with two parameter logistic model (2 PLM), the number of test items for the field testing becomes 78 items.

Intervention Practice. After testing the reasoning skills of pre-service teachers, Professor Tim van Gelder's (2000) argument mapping technique was used to improve the reasoning skill of pre-service teachers who got low reasoning scores in field testing. The intervention plan and procedure are described specifically in the next section.

Data Collection Procedure. Students had to complete Reasoning Skill Test during 1 hour and 15 minutes. After administering the test, data analysis for test development was conducted. Then, based on the reasoning skill levels of pre-service teachers, 60 participants who got the low, moderate and high reasoning skill were trained with an intervention practice during three weeks. After that, their reasoning skills were tested again to assure the predictive validity of the test and how the reasoning skills can be improved.

Data Analysis and Findings

As the first part of the data analysis, a reasoning test development was conducted. The data analysis procedure followed the data analysis process of Hambleton et al. (1991) and Kolen and Brennan (2004).

Confirmatory Factor Analysis. Confirmatory factor analysis was used to establish the four factors structure of the reasoning skills test: analogical, numerical, analytical and abstract reasoning. In this study, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.856 that is indicating sufficient items for each factor. Then, Bartlett's Test of Sphericity was significant ($p < .001$) which means that the variables are highly correlated enough to provide a reasonable basic for factor analysis.

After conducting the principal axis factor analysis, 31 items of 78 items were eliminated because they had low or no loadings with any other factors. By taking out 31 items, the communalities were all above 0.2 and it indicated that the relation between each item and other items is satisfactory. Given these overall indicators, factor analysis was conducted with 47 items.

Checking for Non-speediness of the Test. According to the non-speeded (power) test method (Gulliksen, 1950), the variance ratios of the four sub tests were nearly zero: 0.001 for analogical, 0.009 for numerical, 0.005 for analytical and 0.003 for abstract reasoning. Therefore, it could be confirmed that all tasks of the tests in current study were non-speeded.

Checking the Assumption of Unidimensionality. To investigate the assumption of unidimentionality, a principal factor analysis was conducted. The values of eigenvalue 1, 2, 3, 4, 5, 6, 7 were 5.489, 1.499, 1.266, 1.149, 0.919, 0.825 and so on, and thus eigenvalue 1 was larger enough than other eigenvalues to determine that the test data satisfy the assumption of unidimensionality.

Checking the Conformity of Model and Test Data. Figure 1 clearly shows expected and observed test score distributions for two parameter model. It indicates that actual observed data score distribution is fairly close to theoretical distribution. Therefore, it is concluded that model-data fit is adequate enough to apply IRT model for this test.

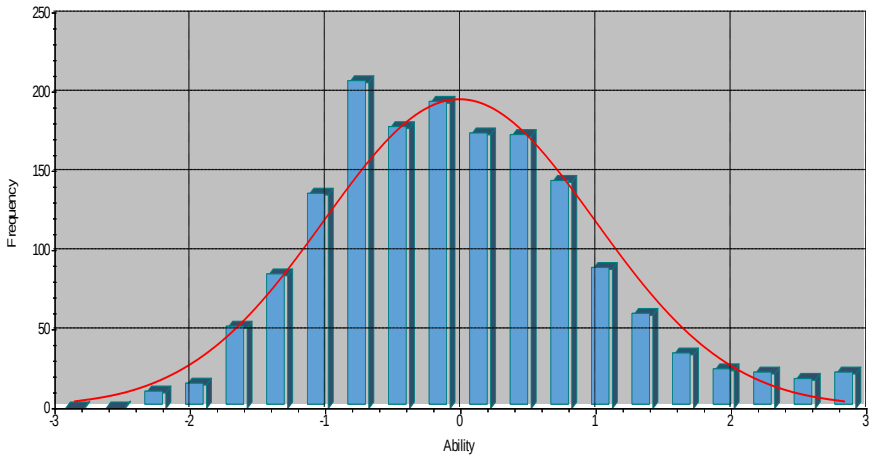

Figure 1 Frequency Distributions of Expected and Observed Scores

Estimation of Item and Ability Parameters. In order to obtain the information which items are appropriate for student teachers, an IRT parameter estimation procedure was carried out with two parameter logistic model (2 PLM) by utilizing BILOG-MG 3 software (Zimowski, Muraki, Mislevy & Bock, 2003). As the items were calibrated with 2 PLM, the characteristics of the items can be described by item difficulty (*b*) and item discrimination (*a*).

For item difficulty (*b*), easier items have lower (negative) difficulty indices and harder items have higher (positive) indices. The items with the difficulty *b* values within -3 to +3 were expected to be selected (Aye Aye Myint, 1997). In this study, all items have *b* values within the range of -3 to +3 and so they are selected as good items.

On the other hand, a higher value of item discrimination (*a*) indicates that the item discriminates between high and low proficiency examinees better. Since there are no items which have more than 2 (*a* value), all items can be acceptable.

Test Information Function. Based on the results of the parameter estimates of the test, test information curve (TIC) was also plotted. Figure 2 illustrates TIC of the 47-item test. SE is the standard error of estimation. The empirical reliability of the test was 0.902.

By looking at Figure 2, it is visually clear that the test is discriminating well among examinees with the range of ability level from -2.5 to +0.4 in the test. The maximum amount of information was I (θ) = 13.5 at θ = -1.15. These test items will be most suitable for student-teachers whose reasoning ability (θ) range is from -2.5 to +0.4. Therefore, it was judged that this test only can provide information well for student teachers with lower reasoning ability; however it may not provide enough information to assess student teachers with high and average reasoning skills.

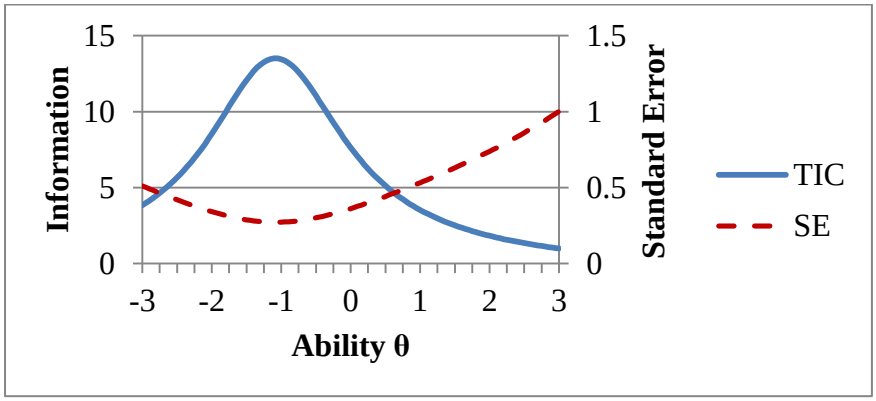

Figure 2 Test Information Curve for the Test with 47 items

Developing an Optimal Reasoning Skill Test. Since the present 47-item reasoning test is relatively easy, it is identified as an item pool and then an optimal reasoning skills test would be constructed by selecting some experimental items from that pool again. To construct systematically, a procedure to build test to meet any desired set of test specification outlined by Lord (1977) was followed.

According to Lord (1977), selecting and calculating the test items were continued again and again until the test information function approximates the target information function to a satisfactory degree. Therefore, among 47 test items, 8 items from each subtest were selected to construct a new test. In Figure 3, a test information curve for an optimal reasoning skills test can be seen. It is visually clear that the test is discriminating well among examinees with the range of ability level from -1.9 to +1.2 in the test. The maximum amount of information was I (θ) = 5.4 at θ = -0.12. Moreover, its empirical reliability is 0.85. Therefore, it can be judged that this optimal test can provide information well for student teachers with normal reasoning ability.

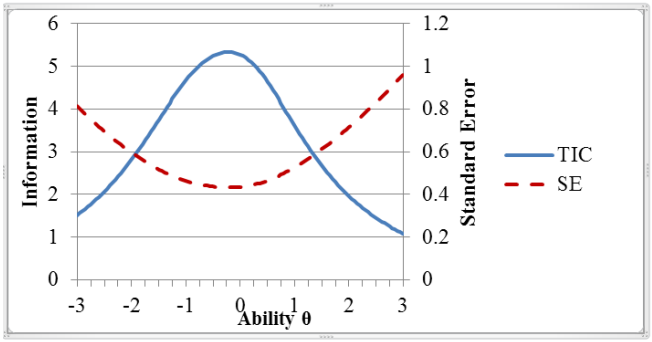

Figure 3 Test Information Curve for the Optimal Test with 32 items

Therefore, the format and content specification of the optimal reasoning skill test become as follows:

Table 1 Table of Content Specification for Optimal Reasoning Skills Test

No.	Names of Subtests	Tasks (Amount of Items)	Total Amount of Items	Time Limit (minute)
1.	Analogical Reasoning	Word (4), Figure (4)	8	3
2.	Numerical Reasoning	Word Problems (4), Data Interpretation (2), Mathematical Puzzles (2)	8	10
3.	Analytical Reasoning	Seating Arrangement (4), Combination (3), Ranking (1)	8	10
4.	Abstract Reasoning	Figure Addition/Subtraction (2), Distribution of three values (3), Distribution of two values (3)	8	7
		Total	32	30

As the second part of data analysis, research findings based on the optimal reasoning test were explored. According to Table 2, it was found that among the four reasoning skills, analytical reasoning skills of pre-service teachers are higher than others ($\bar{X}$=4.97, SD=2.124).

Table 2 Descriptive Statistics for Pre-service Teachers' Reasoning Skills

Reasoning Skills	Minimum	Maximum	Mean	Std. Deviation
Analogical	0	8	4.75	1.729
Numerical	0	8	4.12	1.890
Analytical	0	8	4.97	2.124
Abstract	0	8	3.58	1.925
Total	3	30	17.41	5.252

Again, when these skills were compared by dividing into two groups, it can be seen that pre-service teachers are higher in inductive reasoning than deductive (see Table 3).

Table 3 Mean Comparison for Reasoning Skills by Two Main Factors

Reasoning Skills	Mean	Std. Deviation
Inductive	8.87	2.958
Deductive	8.54	3.328

Then, Table 4 revealed that male pre-service teachers' inductive reasoning is significantly higher than females at α= 0.001 level. However, there are no differences in both deductive reasoning and overall reasoning.

Table 4 Independent Samples *t* Test Results of Reasoning Skill by Gender

	Gender	N	Mean	Mean Difference	*t*	*df*	*p*
Inductive	Male	746	9.18	0.568	3.874	1624	0.000
	Female	880	8.61				
Deductive	Male	746	8.40	-0.269	-1.625	1624	0.104
	Female	880	8.67				
Total	Male	746	17.58	0.299	1.144	1624	0.253
	Female	880	17.28				

After that, the differences of reasoning by university were explored. Since Table 5 showed that there were differences among universities, ANOVA test and post hoc analysis were continued. Based on Table 6 and Table 7, it can be concluded that University 1 is highest and University 3 is lowest significantly in reasoning of pre-service teachers from three universities at α= 0.001 level.

Table 5 Descriptive Statistics for Pre-service Teachers' Reasoning Skills by University

University	N	Mean	Std. Deviation
1	519	20.18	4.374
2	525	17.95	4.861
3	582	14.46	4.787
Total	1626	17.41	5.252

Table 6 ANOVA Result of Reasoning Skills by University

	Sum of Squares	**df**	**Mean Square**	**F**	***p***
Between Groups	9210.933	2	4605.466		
Within Groups	35607.341	1623	21.939	209.919	.000
Total	44818.273	1625			

Table 7 Games-Howell Test Result of Pre-service Teachers' Reasoning Skill by University

(I) University	**(J) University**	**Mean Difference (I-J)**	**Std. Error**	***p***
1	2	2.238*	.286	.000
	3	5.724*	.276	.000
3	1	-5.724*	.276	.000
	2	-3.486*	.290	.000

* The mean difference is significant at the 0.001 level.

Intervention Based Analysis and Results

Based on the quantitative data results, an intervention practice was conducted to improve pre-service teachers' reasoning skills and to confirm the predictive validity of the reasoning skill test based on the quantitative results.

Research Method. As the research method, one group pretest-posttest experimental design was used.

Participants. There were 30 participants from university 1 (highest reasoning) and university 3 (lowest reasoning) respectively and totally 60 participants in this practice. The participants for this study are specifically described in Table 8 by stratum.

Table 8 Number of Participants from Selected Universities of Education

University	Reasoning Groups	Gender		Total
		Male	Female	
University 1	High	5	5	10
	Moderate	5	5	10
	Low	5	5	10
	Total	15	15	30
University 3	High	5	5	10
	Moderate	5	5	10
	Low	5	5	10
	Total	15	15	30
Total		30	30	60

Intervention Protocol. For intervention, a protocol is based on a technique for improving reasoning skills called argument mapping by Tim van Gelder (2000). The researcher joined the email short course (http://www.vangeldermonk.com/free-emailcourse.html) about argument mapping instructed by Dr. Tim van Gelder for three weeks in December 2017. The basic idea of the technique is that the participants create diagrams showing the parts of their reasoning, and how these diagrams are logically related. Myanmar contexts which may be familiar with them were supplemented to the lessons to be convenient for all Myanmar student teachers. Each lesson was managed with two parts: first 30-minute section was for lecture and second 30-minute section was for practicum.

After preparing the protocol, the expert reviews were taken for face validity and content validity by ten experts in the fields of Educational Psychology and Educational Test and Measurement at Yangon University of Education. A pilot practice was performed with a sample of 20 student teachers from Sagaing University of Education in June, 2018. This intervention protocol comprised of six lessons and six periods were taken to practice.

Table 9 Content and Time Limit of Argument Mapping Protocol

Period	Content	Time Limit
1	Making Your Core Argument	1 hour
2	Countering Objections	1 hour
3	Making Your CASE	1 hour
4	Defending Your Assumptions	1 hour
5	Finding Your Hidden Vulnerabilities	1 hour
6	Presenting with Impact	1 hour 15 minutes

Reasoning Skill Test for Posttest. To construct a posttest, 50% (16 items) of posttest items were taken from the pretest items as the common items and 50% of them were from the field testing results. Based on the item parameter estimates, a test information curve for reasoning skill posttest was drawn as in Figure 4. It is visually clear that the test is discriminating well among examinees with the range of ability level from -1.8 to +0.9 in the test. The maximum amount of information was I (θ) = 4.9 at θ = -0.35. Moreover, its empirical reliability is 0.83. Therefore, it can be judged that this posttest is similar to the pretest (see Figure 4) and can provide information

well for student teachers with normal reasoning ability. Hence, the format and content specifications of the posttest were also similar to the pretest.

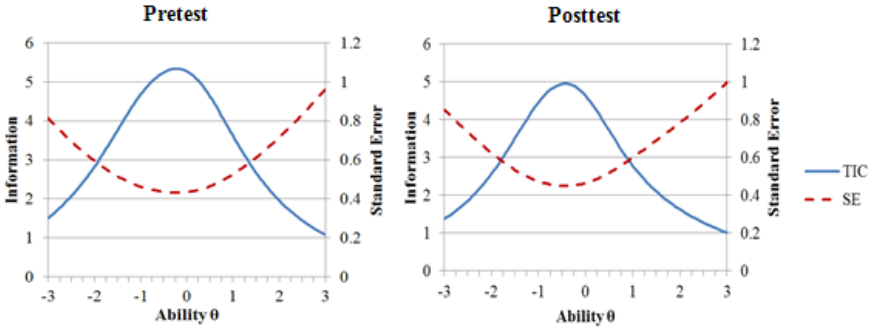

Figure 4 Comparison of Test Information Curves for the Reasoning Skill Pretest and Posttest

Comparison of Reasoning Skill Before and After Intervention. According to paired samples *t* test result, it can be perceived that their reasoning skills after intervention are significantly higher than before intervention ($p < .001$ level). Moreover, the same results were also found in both University 1 and University 3. Therefore, it can be concluded that Argument Mapping Technique intervention practice could well increase the student teachers' reasoning skills (See Table 10 and Figure 5).

Table 10 Paired Samples *t* Test Results of Reasoning Skills Before and After Intervention

University	Intervention	Mean	Std. Deviation	Mean Difference	*t*	*df*	*p*
University 1	Before	17.30	7.77	-2.93*	-8.04	29	0.000
	After	20.23	7.36				
University 3	Before	15.30	7.64	-2.63*	-7.18	29	0.000
	After	17.93	7.22				
Total	Before	16.30	7.71	-2.78*	-10.82	59	0.000
	After	19.08	7.32				

Note. * The mean difference is significant at the 0.001 level.

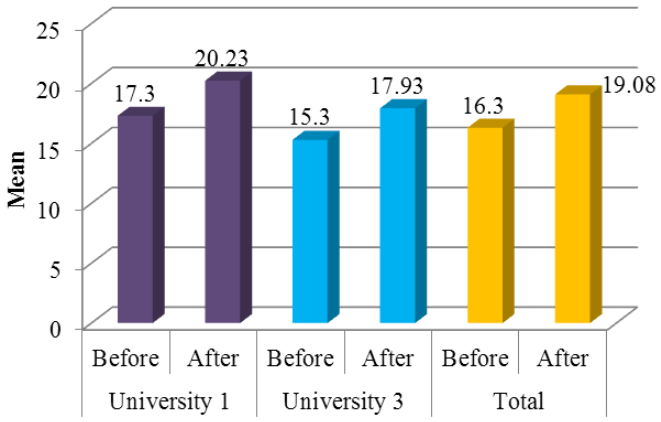

Figure 5 Mean Comparisons of Pre-service Teachers' Reasoning Skills Before and After Intervention

Conclusion and Recommendations

In this new millennium, the world is changing rapidly in science and technology and the changes have the greatest influence on economic, educational, environmental, cultural and social trends of the future. Consequently, these effects also fall on youths' thoughts and actions. They need to think correctly and to do properly. Reasoning skills have become more important in the modern world because there is too much information, and too many choices that come into human's minds.

The foremost responsibility would be the universities. After the students have selected to attend the respective university, they will study about specific knowledge which is expected to use for working in the future. Normally the Universities of Education teaches them academic and teacher education knowledge because this is their main duty. In the meantime, the challenges of the modern era would like the graduated students to have some other skills to work such as reasoning skills.

Future professionals are no longer to satisfy with their own expertise only, however they need to constantly study, learn, review, analyze, and classify the thinking ability to fit the needs of society in the future world. For that reason, the Universities of Education should consider their teaching techniques on how to improve the students' working skills.

In order to fulfill the goal of teacher education programs and improve students' reasoning skills, this study finally offers the following recommendations based on research findings and literature reviews:

- The aims of learning and teaching may need to be revised to improve the skills which are necessary for working after graduation.
    - The curriculum contents and implementation of the courses need to foster students' in-depth understanding of subject knowledge, analyses of theoretical background, and higher order cognitive competencies. This emphasis of teaching strategy and curriculum materials can enhance teacher educators' and pre-service teachers' recognition concerning "Thinking is learning".
    - The culture of teaching and learning in the classroom should provide more opportunities for student teachers to discuss and give the reason to their teachers.
    - Teacher educators should discuss and guide occasionally their trainees about how to solve classroom problems and how to reason methodically a problem.
    - Pre-service teachers should be sporadically provided with the skills test, such as, reasoning skills test, so that they know their levels of these skills since the beginning of their university life and it will help them to improve their working skills by practice.
    - To improve the pre-service teachers' reasoning skills, the teacher educators should use any practice like argument mapping technique performed in this study.
    - A series of campus symposia for public discussions on academic issues and social events might assist students to visualize the functions of reasoning skills and create beneficial campus environment facilitating reasoning skills development.

To sum up, since education is to prepare citizens with reasoning skills and to create more rational society or culture, it is hoped that the contributions of this study can not only provide insight to know about reasoning skill but also be a support for upgrading teacher education in Myanmar.

Acknowledgements

First of all, I would like to acknowledge my indebtedness to Dr. Aye Aye Myint (Retired Rector, Yangon University of Education), Dr. Saw Pyone Naing (Rector) and Dr. Myat Myat Thaw (Pro-rector) from Sagaing University of Education, for giving me the opportunity to undertake research and write up of this paper. I wish to express my warmest gratitude to Dr. Khin Hnin Nwe (Associate Professor & Head, Department of Educational Psychology, Sagaing University of Education) who warmly assisted and guided me in conducting this research. I am truly grateful to my academic supervisor Dr. Khin Pyone Yi (Retired Professor & Head, Department of Educational Psychology, Yangon University of Education), co-supervisor Dr. Khin Thuza Saw (Retired Principal, Thingangyun Education College) for their patient guidance and their insightful comments through out this research.

References

Aye Aye Myint. (1997). Investigation of the numerical reasoning ability of Myanmar high school students. *Bulletin of the Graduate School of Education and Human Development*, Toyko University, Press, 37, pp. 165-176.

Cattell, R. B. (1963). Theory of fluid and crystallized intelligence: A critical experiment. *Journal of Educational Psychology*, *54*(1), 1-22.

Deloache, J. S., Miller, K. F., & Pierroutsakos, S. L. (1998). Reasoning and problem solving. In Kuhn, D. & Siegler, R. S. (Eds.), *Handbook of child psychology: Cognition, perception and language* (5th ed., Vol. 2, pp. 801-850). New York: Wiey.

DeMars, C. (2010). *Item Response Theory*. New York, Oxford University Press.

Fatima, S. K. (2008). *Reasoning ability of adolescent students*. Study conducted in Rangareddy District of Andhra Pradesh, India.

Fischhoff, B., Crowell, N.A., & Kipke, M. (1999). *Adolescent decision making: implications for prevention programs* (Summary of a Workshop). Washington DC: National Academy Press.

Galotti, K. M. (2004). *Cognitive psychology: In and out of the laboratory (3rd ed.)*. Wadsworth: Thomson Learning Academic Resource Center.

Gulliksen, H. (1950). *Theory of mental tests*. New York: Wiley.

Hambleton, Ronald. K., Swaminathan, H., & Rogers, H. Jane. (1991). *Fundamentals of Item Response Theory*. Newbury Park, CA: Sage Publications, Inc.

Jeotee, Kunchon. (2012). *Reasoning skills, problem solving ability and academic ability: implications for study programme and career choice in the context of higher education in Thailand* (Unpublished doctoral Dissertation). Durham University, Thailand.

Johnson-Laird, P.N., & Shafir, E. (1993). The interaction between reasoning and decision making: an introduction. *Cognition*, 49, 2, 1-9.

Kant-Studien. (1987). Kant's system of perspectives. In Stephen Palmquist, *Knowledge and Experience - An Examination of the Four Reflective Perspectives in Kant's Critical Philosophy*, pp.170-200. Lanham: University Press of America (1993).

Khin Zaw, Dr. (2001a). *Advanced educational psychology*. PhD/ MEd Research Reference. Yangon: Yangon Institute of Education, YIOE.

Kirwin, C. (1995). Reasoning. In Ted Honderich (ed.). *The Oxford Companion to Philosophy*. Oxford: Oxford University Press.

Mangal. S. K. (2012). *Advanced educational psychology*. 2nd ed. New Delhi: PHL Learning Private Limited.

Osman, Magda. (2004). An evaluation of dual-process theories of reasoning. Retrieved January 20, 2016 from http://www.researchgate.net/publication/7864887.

Savill, O. (2011). *What are numerical reasoning tests: the difference between numerical reasoning and numerical comprehension*? Retrieved March 2, 2016 from www.assessment.co.uk.

Tim van Gelder, Dr. (2000). Argument mapping short course. Retrieved December 1, 2018 from http://www.vangeldermonk.com/free-emailcourse.html

Wilhelm, O. (2005). Measuring reasoning ability. In O. Wilhelm & R. W. Engle (Eds.), *Handbook of measuring and understanding intelligence* (pp. 373-392). Thousand Oaks, CA: Sage Press.

Zinmowski, M., Muraki, E., Mislevy, R., & Bock, D. (2003). *BILOG-MG [Computer software and manual]*. Lincolnwood, IL: Scientific Software International.