Perceptions of In-service Mathematics Teachers towards Enhancing Students' Critical Thinking Skills in Mathematics

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Abstract: Critical thinking is important in societal life, and in the education system such as ways of learning mathematics, of teaching mathematics, and a goal of schooling. Therefore, the purpose of this study was to investigate the perceptions of in-service mathematics teachers towards enhancing students' critical thinking skills in mathematics. Exploratory survey design and quantitative research method were used. A total of 102 in-service mathematics teachers were taken using stratified random sampling from the pools of the in-service mathematics teachers of postgraduate diploma in teaching (PGDT) and master's programs. The data were collected by a Likert scale, and analyzed by mean, standard deviation, correlation, independent sample t-test, one-way ANOVA and MANOVA. The results showed that most of the in-service mathematics teachers felt they teach using self-reflection and self-evaluation about thinking processes, teach the initial and rehearsal strategies for complex tasks, apply questioning strategies in enhancing students' critical thinking skills in Mathematics. However, varying in terms of program type and level of teaching which demands further investigation.

Key words: Critical thinking, perception, program, level of teaching, service year, mathematics

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Introduction

One of the objectives of mathematics learning is to help students apply critical thinking and use mathematics as a way of reasoning and have an ability to solve problems. In general, teachers teach mathematics to their students by employing traditional approach, and research result shows that the students of Junior High School have not reached optimally the objective of mathematics learning yet. In other side, contextual teaching and learning have several components which theoretically can enhance critical thinking (Rohayati, 2007).

Scriven & Paul (2007) defined critical thinking as "the intellectually disciplined process of actively and skilfully 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". Critical thinking has also been referred to as meta-cognition (Tempelaar, 2006) or the process of "thinking about thinking" as defined and originally purposed by Flavell (1979). Facione (2007) also defined critical thinking as-reflective decision-making and thoughtful problem solving about what to believe and do. Similarly, Halpern (2003) defined critical thinking as-cognitive skills and strategies that increase the likelihood of a desired outcome… thinking that are purposeful, reasoned, and goal-directed-the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions.

Ennis (in Sabandar, 2009) suggested six basic elements that are necessarily considered in critical thinking: *focus* on situation or condition that displays and describes main problem; *reasons* underpin arguments that support making inference, finding facts and evidences that support reasons of making inferences so the inference would be true and can be acceptable, as well as identifying and justifying the problem; *inference* questions and consideration of any proposed reasons; *situation* is condition or situation of environment around us;

clarification is an act of inquiring considerations and analogies made from available information; *overview* is a process of comprehending all sides of the problem, conclusion and solution to the problem. Krulikdan (1995) also presented in his research that the eight descriptions of critical thinking are namely examining, relating and evaluating all aspects of a situation or problem, focusing on part of a situation or problem, collecting and organizing information, validating and analyzing information, remembering and analyzing information, determining an answer logically or not, has analytic and reflective nature. Watson & Glaser (1980) conducted measurement of critical thinking using tests including five indicators, namely inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments. Yeh (2002) stated that the critical thinking skill is a cognitive process containing analysis, comment, evaluation, inference, explanation, and self-regulating.

Critical thinking may also involve logical reasoning and ability to separate facts from opinions, examine information critically with evidence before accepting or rejecting ideas and questions in relation to the issue at hand. In other words, it makes individuals to think, question issues, challenge ideas, generate solutions to problems and take intelligent decisions when faced with challenges (Semil, 2006). Critical thinking also involves deep reasoning and a consideration of what we received rather than a forthright acceptance of different ideas (Mansoor, and Pezeshki, 2012). This means that ideas and suggestions from people about a phenomenon cannot be fully accepted if it does not go through the systematic and logical process of finding the truth. In applying Critical thinking in school settings, it is necessary to develop thinking skills because people who think critically would be able to understand the logical connections between ideas construct and evaluate arguments, detect common mistakes in reasoning and solving problems systematically, and reaching at conclusions supported with evidence.

The context of this study critical thinking is the power of students to think mathematically and to use mathematics to help them solve problems in their daily and working lives. With this intent critical thinking is based on the teachers' activities that enhance students' critical thinking and have three steps namely 'teaching self-reflection and self-evaluation about thinking processes'; 'teaching the initial and rehearsal strategies for complex tasks'; and 'questioning strategies in enhancing critical thinking.'

Importance of Critical Thinking

Critical thinking as mentioned earlier is needed in societal life, because in a societal life people always face problems that need to be solved and data are needed for solving problems in order to make a decision logically and accurately. Critical thinking as an important thing for the ability to think critically is generally regarded as major goal of academic instruction. It also plays an important role in many kinds of occupations, particularly those in which careful, analytical thinking is an essential part of the job (Watson & Glaser, 1980).

In the education system, mathematical thinking is important in three ways: as a way of learning mathematics; for teaching mathematics; and as a goal of schooling. If students' ability to think mathematically is an important outcome of schooling, then it is clear that mathematical thinking must feature prominently in lessons. If students are to become good mathematical thinkers, then mathematical thinking needs to be a prominent part of their education. In addition, however, students who have an understanding of the components of mathematical thinking will be able to use these abilities independently to make sense of mathematics that they are learning (Stacey, 2008).

Being able to use mathematical thinking in solving problems is one of the most fundamental goals of teaching mathematics. It is an ultimate goal of teaching that students will be able to conduct mathematical

investigations by themselves, and that they will be able to identify where the mathematics they have learned is applicable in real world situations. In the phrase of the mathematician Halmos (1980), problem solving is “the heart of mathematics”. However, whilst teachers around the world have considerable successes with achieving this goal, especially with more able students, there is always a great need for improvement, so that more students get a deeper appreciation of what it means to think mathematically and to use mathematics to help in their daily and working lives.

The ability to think mathematically and to use mathematical thinking to solve problems is an important goal of schooling. In this respect, mathematical thinking will support science, technology, economic life and development in an economy. Increasingly, governments are recognising that economic well-being in a country is underpinned by strong levels of what has come to be called ‘mathematical literacy’ (PISA, 2006) in the population. Mathematical literacy is a term popularised especially by the OECD’s PISA program of international assessments of 15 year old students. Mathematical literacy is the ability to use mathematics for everyday living, and for work, and for further study, and so the PISA assessments present students with problems set in realistic contexts. The framework used by PISA shows that mathematical literacy involves many components of mathematical thinking, including reasoning, modelling and making connections between ideas. It is clear then, that mathematical thinking is important in large measure because it equips students with the ability to use mathematics, and as such is an important outcome of schooling.

Critical thinking teaching strategy is an active process in promoting and enhancing students’ performance in schools. Listening to lectures in the classroom, to most students is a passive activity because students only listen and do not have the opportunity to ask questions when the lecture is going and this make the class dull. The intellectual skills of Critical Thinking--analysis, synthesis, reflection, etc.--must be learned by actually performing them (Chukwuyenum, 2013).

Instructional Methods Enhancing Critical Thinking

Traditional instructional methods use too many facts and not enough conceptualization; too much memorizing and not enough thinking. Therefore, lecture and rote memorization do not promote critical thinking. Instructional strategies that employ students' higher-order thinking skills lead to improved critical thinking skills (Wong, 2007).

Promoting critical thinking and *problem solving* in mathematics education is crucial in the development of successful students. Critical thinking and problem solving go hand in hand. In order to learn mathematics through problem solving, students must also learn how to think critically (M˘arcut, 2005). *Heuristic teaching methods* encourage students to "learn, discover, understand, or solve problems on their own, as by experimenting, evaluating possible answers or solutions, or by trial and error" (Dictionary.com, 2007). A similar study suggested that *problem-based learning activities* promoted "critical thinking and problem-solving skills; active participation in the learning process including self-direction, identification of own learning needs, teamwork, creative discussion, and learning from peers; and the integration and synthesis of a variety of knowledge" (Gurses, Acikyildiz, Dogar, & Sozbilir, 2007). Kumar and Natarajan (2007) also found problem-based learning environments to increase students' thinking skills and knowledge acquisition. Saraoghu, Yobaccio, & Louton (2000) studied *hands-on activities* that required students to think critically and apply their knowledge to specific tasks.

Instruction that supports critical thinking uses *questioning techniques* that require students to analyze, synthesize, and evaluate information to solve problems and make decisions (think) rather than merely to repeat information (memorize). Haynes and Bailey (2003) emphasized in their research the importance of asking the right questions to stimulate students' critical thinking skills. Other researcher Hemming (2000) also focused on integrating *questioning techniques* into class

discussions to support an educational environment where students can demonstrate and practice critical thinking skills.

One approach of improving student outcomes has been to enhance the teaching skills of the teachers in order to generate critical and reflective thinking skills among students. Often this has resulted in calls for teachers to learn and implement *inquiry-guided learning techniques* which are presumed to improve student performance in terms of participation, understanding of course concepts, engagement, critical thinking, and reflective thinking (Atkinson & Hunt, 2008; Hunt & Touzel, 2009; Mollborn & Hoekstra, 2010; Pedersen, 2010). In the research of Garret and Heyl (1976) results showed that *inquiry teaching and learning* showed a lot of positive impact in stimulating students' thinking skills. Inquiry teaching allows students to participate actively in solving problems or answering questions posed by teachers. Students will make efforts to answer the questions posed by teachers and teachers act as facilitators until students get the intended answers.

The use of *debates* as an instructional strategy helps develop students' critical understanding in a specialist subject area by encouraging them to explain and justify their reasoning (Pilkington & Walker, 2003). Debating “is a structured contest of argumentation that forces the participants to consider not only the facts of a situation but the implications as well. Participants think critically and strategically about both their own and their opponent's position”.

Statement of the Problem

The traditional way of teaching Mathematics in Ethiopian public secondary schools is dominantly teacher-centered approach. This method sometimes involves repetition and memorization of previously taught material by filling the students’ minds with knowledge of Mathematics without explaining in detail the process of analyzing, evaluating and arriving at a conclusion. In addition, these processes may not make the students to be critical in thinking because some of

them might find it difficult to apply the knowledge acquired to solve mathematical problems in a new situation. Critical thinking skills have been adopted in Ethiopia as one of the nation's educational goals to make students creative (MoE, 2009). However, it has not been fully incorporated and given wide recognition as one of the major concepts in the school curriculum. Owolabi (2003) explained that the failure rate in Mathematics might be attributed among other reasons to lack of interpreting, explaining, analyzing and evaluating mathematics questions. Teachers generally agree that they want their students to develop and practice critical thinking skills. These skills include the ability to evaluate and interpret experiments, draw conclusions from data, make predictions, and identify assumptions. From this point, however, teachers apply different teaching strategies. Therefore, the study aims to assess the perceptions of in-service mathematics teachers towards enhancing students' critical thinking skills in mathematics.

Objective of the Study

The general objective of this study was to assess the perception of in-service mathematics teachers enhancing students' critical thinking skills in mathematics.

The specific objectives of the study were:

1) To analyze the extent of the in-service mathematics teachers perceptions towards enhancing students' critical thinking skills in mathematics,
2) To check whether there are significant differences in the responses of the in-service mathematics teachers enhancing students' critical thinking skills in mathematics with respect to program, level of teaching and service year.

3) To see the interaction effect between program, level of teaching and service year on the component variables of enhancing students' critical thinking skills in mathematics.

Research Questions

The research questions for the study were:

1) To what extent do the in-service mathematics teachers perceive they enhance students' critical thinking skills in mathematics?
2) Is there a significant difference in the perceptions of the in-service mathematics teachers towards enhancing students' critical thinking skills in mathematics with respect to program?
3) Is there a significant difference in the perceptions of the in-service mathematics teachers towards enhancing students' critical thinking skills in mathematics with respect to level of teaching?
4) Is there a significant difference in the perceptions of the in-service mathematics teachers towards enhancing students' critical thinking skills in mathematics with respect to service year?
5) Is there significant interaction effect between program, level of teaching and service year on the component variables of enhancing students' critical thinking skills in mathematics?

Material and Methods

Research Design

The present study used exploratory survey design. The method used for this study was quantitative research method and it focused on a Likert scale questionnaire.

Population and Sampling Method

The population for this study consisted of all 306 in-service mathematics teacher trainees in Addis Ababa University. 102 of them were selected using stratified random sampling. These 102 were classified in terms of program as master teacher trainees (63) and PGDT teacher trainees (39); in regards school placement teachers teaching in primary schools (30), in secondary schools (32) and in preparatory schools (40); and based on service year teachers of short teaching service year – less than 11 years (38), average teaching service year – between 11 and 20 years (32), and long years of teaching service – more than 20 years (32). These years of service are classified based on the ranks for teachers set by the Ministry of Education where the first two ranks are considered shorter service years, the next two ranks considered as average and those of the remaining higher ranks considered as long service years.

Instruments of Data Collection

A Likert scale on "In-service mathematics teachers' perceptions on enhancing students' critical thinking skills in mathematics" were developed from PBS Teacherline (2006), The State of Queensland (Queensland Studies Authority) (2005) & Potts (1994). The scale had 19 items divided into three major components namely ‘teaching self-reflection and self-evaluation about thinking processes’; ‘teaching the initial and rehearsal strategies for complex tasks’; and ‘questioning

strategies in enhancing critical thinking'. The first two components had six items and the last component had seven items. All the scales were a 1-5 Likert-type scale and the respondents were asked to respond to each item using a five point scale ranging from strongly agree to strongly disagree where strongly agree = 5, agree = 4, neutral = 3, disagree = 2 and strongly disagree = 1.

Validity and Reliability of the Instruments

The scale of teachers' perceptions on enhancing students' critical thinking skills in mathematics were reviewed based on the comments of professionals for the face and content validity. A pilot study was conducted to determine the validity and reliability of the scales on thirty summer in-service mathematics teachers who are not included in the main study from Addis Ababa University. From the pilot study the alpha coefficient of Cronbach yielded 0.740 in the subscale of 'teaching self-reflection and self-evaluation about thinking processes'; 0.759 in the subscale of 'teaching the initial and rehearsal strategies for complex tasks'; 0.759 in the subscale of 'questioning strategies in enhancing critical thinking'; and 0.873 in the scale of 'enhancing students' critical thinking skills in mathematics'. The final data were collected with these piloted instruments whose reliabilities at the end were also in the acceptable range (0.748, 0.766, 0.768, and 0.884 respectively). The Cronbach Alpha Coefficients of reliability for all variables indicated that they have acceptable internal-consistency reliability.

Methods of Data Analyses

Since the scale was an ordinal of 5 levels Likert scale and the skewness of the distribution for all 19 items lied between -1 and +1, this indicated that the data is not significantly different from normal. These justify that the variable is distributed approximately normally and the possibility to use inferential statistics. Therefore, the data analysis techniques used for this study were Mean, Standard Deviation,

Independent t-test, One way ANOVAs and Multivariate analysis of variance (MANOVA).

Procedure of Data Collection

The scales of teachers' perceptions were distributed to professionals in the area of mathematics education from Addis Ababa University to comment on it. The main comments given were deleting some items for the sub-scale due to redundancies, merging two items in one since they have similar concepts, shortening the lengthy statements and editing the language of the sentences. Then the questionnaires were distributed to thirty summer in-service mathematics teachers as a pilot study to fill the questionnaire. After checking the validity and reliability of the instrument, then the questionnaires were distributed in 2015 academic year to the in-service teachers who joined PGDT or Masters Summer program in mathematics at Addis Ababa University and who are in the final year for graduation, and were filled at the same time.

Results

The first research question was to what extent do the in-service mathematics teachers perceive enhancing students' critical thinking skills in mathematics? In order to answer this question, 19 items were administered to the respondents to assess the extent of the teachers teaching self-reflection and self-evaluation about thinking processes; teaching the initial and rehearsal strategies for complex tasks; and questioning strategies in enhancing critical thinking.The items were rated using a five - point rating scale starting from strongly agree to strongly disagree. Table 1 presents the descriptive statistics of the responses of in-service mathematics teachers in enhancing students' critical thinking skills in Mathematics.

Table 1: Descriptive statistics of the responses of In-service Mathematics Teachers enhancing students' critical thinking skills in Mathematics

No	Variables	N	Mean	SD
1	I challenge pre-existing ideas (beliefs, concepts, and misconceptions) by presenting situations that students are unable to explain-paradoxes, dilemmas, and perplexities.	102	3.53	1.08
2	I guide students in how to do systematic inquiry, allowing them to think independently, but preventing them from pursuing dead ends and simplistic answers.	102	3.90	.896
3	I encourage students to reflect upon and make sense of new information by making judgments in writing or discussions about its relevance, telling in their own words how to integrate their findings with their previously existing ideas, opinions, or approach	102	4.00	.901
4	I encourage and guide students to formulate hypotheses, speculate on consequences, guess, brainstorm, and discuss how their thinking processes have worked to change their ideas	102	3.98	.912
5	I monitor and correct inefficient strategies.	102	3.71	.973
6	I encourage continuous reflection of beliefs about thinking, thinking processes, and evaluation of effectiveness	102	3.97	.877
	Teaching self-reflection and self-evaluation about thinking processes	**102**	**3.85**	**.620**
7	I include individualized options in lesson plans designed to teach higher order thinking	102	3.52	1.12
8	I teach how to preview, question, read, reflect, recite, and review when learning from written materials	102	4.03	.780
9	I provide instruction in "abstracting, analyzing, outlining, summarizing, and generalizing".	102	3.82	.942
10	I emphasize broad problem-solving strategies, algorithms, or heuristics.	102	3.76	1.01
11	I provide practice for routines of different strategies, algorithms, and heuristics until they are over learned, so that their use becomes fast, effortless, and consistent.	102	3.56	1.00
12	I teach specific learning strategies by talking about the strategy, modelling it while thinking out loud, and providing opportunities for practice.	102	3.90	.79
	Teaching the initial and rehearsal strategies for complex tasks	**102**	**3.76**	**.641**
13	I ask questions of all students equally, calling on non-volunteers as well as volunteers.	102	3.96	1.07
14	To stimulate curiosity or demand problem solving, I ask questions about paradoxes, dilemmas, and novel problems and approaches.	102	3.34	1.01
15	I encourage students generate their own questions about topics.	102	4.10	1.02
16	I start with lower-order questions, remediating as needed, and lead up to higher-order questions.	102	4.31	.797
17	I provide wait time after a question because students differ in the rate at which they respond.	102	3.99	.806
18	I prepare questions that go beyond simple recall of factual information to focus on advanced levels of comprehension, such as How? Why? and How well?	102	3.89	.90
19	I diagnose students' existing schemata by asking probing questions	102	3.78	.934
	Questioning strategies in enhancing critical thinking	**102**	**3.90**	**.604**
	Enhancing students' critical thinking skills in Mathematics	**102**	**3.84**	**.521**

As can be seen from the above table for investigating the first component of students critical thinking skills***'teaching self-reflection and self-evaluation about thinking processes'***, the items which reads, 'challenging pre-existing ideas by presenting situations that students are unable to explain-paradoxes, dilemmas, and perplexities', 'guiding students how to do systematic inquiry, allowing them to think independently, but preventing them from pursuing dead ends and simplistic answers', 'encouraging students to reflect upon and make sense of new information by making judgments in writing or discussions about its relevance, telling in their own words how to integrate their findings with their previously existing ideas, opinions, or approach', 'encouraging and guiding students to formulate hypotheses, speculate on consequences, guess, brainstorm, and discuss how their thinking processes have worked to change their ideas', 'monitoring and correcting inefficient strategies', and 'encouraging continuous reflection of beliefs about thinking, thinking processes, and evaluation of effectiveness' were rated with mean score values of 3.53, 3.90, 4.00, 3.98, 3.71 and 3.97 respectively, implying that all components of teaching self-reflection and self-evaluation about thinking processeswere above average. The second area of critical thinking skills is ***'teaching the initial and rehearsal strategies for complex tasks'***, the items of which indicate that 'including individualized options in lesson plans designed to teach higher order thinking', 'teaching how to preview, question, read, reflect, recite, and review when learning from written materials', 'providing instruction in abstracting, analyzing, outlining, summarizing, and generalizing', 'emphasizing broad problem-solving strategies, algorithms, or heuristics', 'providing practice for routines of different strategies, algorithms, and heuristics until they are over learned', and 'teaching specific learning strategies by talking about the strategy, modelling it while thinking out loud, and providing opportunities for practice' that were rated with mean score values of 3.52, 4.03, 3.82, 3.76, 3.56and 3.90 respectively, implying that all components of teaching the initial and rehearsal strategies for complex tasks were also above average. The third area is***'questioning***

strategies in enhancing critical thinking' and under this the items include 'asking questions of all students equally, calling on non-volunteers as well as volunteers', 'asking questions about paradoxes, dilemmas, and novel problems and approaches', 'encouraging students generate their own questions about topics', 'starting with lower-order questions, remediating as needed, and lead up to higher-order questions', 'providing wait time after a question because students differ in the rate at which they respond', 'preparing questions that go beyond simple recall of factual information to focus on advanced levels of comprehension', and 'diagnosing students' existing schemata by asking probing questions' which were rated to have mean score values of 3.96, 3.34, 4.10, 4.31, 3.99, 3.89 and 3.78 respectively, implying that all components of *questioning strategies in enhancing critical thinking* were all above average. For the aggregate of all the items of '***enhancing students' critical thinking skills in Mathematics'*** the average value of the responses is 3.84, which is above average.

Below is the analysis for the second research question 'Is there significant differences in the perception of the in-service mathematics teachers towards enhancing students' critical thinking skills in mathematics with respect to program?'

Program

In order to examine the significance of the differences on in-service mathematics teachers' perception towards enhancing students' critical thinking skills in mathematics with respect to their program an independent samples t-test was used, since the assumptions of independence, normality of the data and homogeneity of variances were met. That is the data are independent since PGDT and Masters Programs are not matched and there is no reason to believe that the scores of one participant are not related systematically to scores of the others. In addition, since the Levene's test of F-test for equality of variances had p values greater than .05, therefore PGDT and Masters Programs were believed to have equal variances for all dependent

variables. Finally the dependent variables are normally distributed within each population, since for both PGDT and Masters Programs the skewness values are less than one which indicates that the dependent variables are approximately normal for both PGDT and Masters Programs. Table 2 below shows descriptive statistics and independent samples t-test for the extent of in-service mathematics teachers in enhancing students' critical thinking skills in mathematics with respect to the program they attend.

Table 2: Descriptive statistics and t-test for the responses of in-service mathematics teachers in enhancing students' critical thinking skills in mathematics with respect to their program

Components	Program	N	M	SD	t	df	p
Teaching self-reflection and self-evaluation about thinking processes	PGDT	39	3.974	.61361	1.654	100	.101
	Master	63	3.767	.61532			
Teaching the initial and rehearsal strategies for complex tasks	PGDT	39	3.863	.59465	1.287	100	.201
	Master	63	3.696	.66434			
Questioning strategies in enhancing critical thinking	PGDT	39	4.004	.49756	1.363	100	.176
	Master	63	3.837	.65659			
Enhancing students' critical thinking skills in Mathematics	PGDT	39	3.950	.45387	1.709	100	.091
	Master	63	3.770	.55138			

From Table 2, the descriptive statistics showed that the mean response values of in-service teachers attending PGDT mathematics teachers program had greater mean score than that of the in-service teachers attending Master program for all component variables related to critical thinking skills:teaching self-reflection and self-evaluation about thinking processes, teaching the initial and rehearsal strategies for complex tasks, questioning strategies in enhancing critical thinking, and enhancing students' critical thinking skills in mathematics. From the same table an independent samples t-test indicate that the t-values do not reveal statistically significant difference between

teachers attending PGDT and Masters mathematics teacher programs in the cases of teaching self-reflection and self-evaluation about thinking processes($t_{(100)}$ = 1.654, p > 0.05), teaching the initial and rehearsal strategies for complex tasks($t_{(100)}$ = 1.287, p > 0.05), questioning strategies in enhancing critical thinking($t_{(100)}$ = 1.363, p > 0.05), and enhancing students' critical thinking skills in mathematics($t_{(100)}$ = 1.709, p > 0.05). Thus, in-service teachers attending PGDT and Master mathematics teachers programs had similar perceptions in theirteaching self-reflection and self-evaluation about thinking processes, teaching the initial and rehearsal strategies for complex tasks, questioning strategies in enhancing critical thinking, and enhancing students' critical thinking skills in mathematics.

Below is the analysis for the research question 'Is there significant differences of the in-service mathematics teachers in enhancing students' critical thinking skills in mathematics with respect to grade level they teach?'

Level of Teaching

One-way ANOVA test was used to see the significance of differences of the in-service mathematics teachers in enhancing students' critical thinking skills in mathematics with respect to level they teach, since the assumptions of independence, normality of the data and homogeneity of variances were equally met fulfilling the conditions outlined previously, and the Levene's test of F-test for equality of variances had p values greater than .05 for all dependent variables. Finally the dependent variables were also found to be normally distributed within each population, since for each primary, secondary and preparatory school teachers the skewness values are less than one, which indicates that the dependent variables are approximately normal for each level teachers. Table 3 shows descriptive statistics and ANOVA test for in-service mathematics teachers in enhancing students' critical thinking skills.

Table 3: Descriptive statistics and ANOVA test for the responses of in-service mathematics teachers enhancing students' critical thinking skills in mathematics with respect to level of teaching

Components	Level of Teaching	N	M	SD	F	P
Teaching self-reflection and self-evaluation about thinking processes	Primary	30	3.9667	.59274	4.153	.019
	Secondary	32	4.0000	.57580		
	Preparatory	40	3.6333	.62725		
Teaching the initial and rehearsal strategies for complex tasks	Primary	30	3.7889	.57558	2.363	.099
	Secondary	32	3.9271	.57258		
	Preparatory	40	3.6042	.71281		
Questioning strategies in enhancing critical thinking	Primary	30	3.9714	.52843	1.534	.221
	Secondary	32	3.9955	.48883		
	Preparatory	40	3.7714	.71961		
Enhancing students' critical thinking skills in Mathematics	Primary	30	3.9123	.44837	3.538	.033
	Secondary	32	3.9753	.44014		
	Preparatory	40	3.6750	.59461		

From Table 3, the descriptive statistics showed that the mean response values of mathematics teachers teaching in secondary schools had the highest and mathematics teachers teaching in preparatory schools had the least responses on all variables that includeteaching self-reflection and self-evaluation about thinking processes, teaching the initial and rehearsal strategies for complex tasks, questioning strategies in enhancing critical thinking, and enhancing students' critical thinking skills in mathematics. From Table 3, as the ANOVA test indicated, F-values do not show statistically significant difference between the level of teaching groups for teaching the initial and rehearsal strategies for complex tasks($F_{(2, 99)} = 2.363$, $p > .05$) and questioning strategies in enhancing critical thinking($F_{(2, 99)} = 1.534$, $p > .05$), but there were statistically significant differences between the level of teaching groups for teaching self-reflection and self-evaluation about thinking processes ($F_{(2, 99)} = 4.153$, $p < .05$) and enhancing students' critical thinking skills in mathematics($F_{(2, 99)} = 3.538$, $p < .05$). These indicate that

mathematics teachers teaching in primary, secondary and preparatory schools had nearly similar in the responses of the variables teaching the initial and rehearsal strategies for complex tasks and questioning strategies in enhancing critical thinking.

Since the variables ‘teaching self-reflection and self-evaluation about thinking processes’and ‘enhancing students' critical thinking skills in mathematics’ made statistically significant differences with respect to level of teaching, Tukey HSD test was used to compare the two variables with respect to the level of teaching. Table 4 below indicates the Tukey HSD tests of the significance of mean difference of scores of teaching self-reflection and self-evaluation about thinking processes and enhancing students' critical thinking skills in mathematicswith respect to level of teaching.

Table 4: ***Tukey test of the significant mean difference of scores of teaching self-reflection and self-evaluation about thinking processes and enhancing students' critical thinking skills in mathematics with respect to level of teaching***

Components	Level (I)	Level (J)	MD (I-J)	SE	p
Teaching self-reflection and self-evaluation about thinking processes	Primary	Secondary	-.03333	.15285	.974
		Preparatory	.33333	.14526	.061
	Secondary	Preparatory	.36667(*)	.14264	.031
Enhancing students' critical thinking skills in Mathematics	Primary	Secondary	-.06305	.12929	.877
		Preparatory	.23728	.12288	.135
	Secondary	Preparatory	.30033(*)	.12066	.038

** The mean difference is significant at the .05 level.*

The Tukey HSD Test from Table 4 above indicates that the mathematics teachers teaching in the secondary schools made significant difference with mathematics teachers teaching in the preparatory schools (MD = .36667, $p < .05$) for the variable teaching self-reflection and self-evaluation about thinking processes. Similarly, the mathematics teachers teaching in the secondary schools made significant difference with mathematics teachers teaching in the

preparatory schools (MD = .30033, $p < .05$) for the variable enhancing students' critical thinking skills in mathematics. These indicate that the mathematics teachers teaching in the preparatory schools responded significantly and negatively that deviated from the mathematics teachers teaching in the secondary schools in the variablesteaching self-reflection and self-evaluation about thinking processes and enhancing students' critical thinking skills in mathematics.

Below is the analysis of the fourth research question 'Is there significant differences of the in-service mathematics teachers in enhancing students' critical thinking skills in mathematics with respect to service year?'

Service Year

In a similar way, One-way ANOVA test was used to see the significance differences of the in-service mathematics teachers enhancing students' critical thinking skills in mathematics with respect to service year after ensuring the assumptions of independence, normality of the data and homogeneity of variances as mentioned thereof. Table 5 shows descriptive statistics and ANOVA test for in-service mathematics teachers in enhancing students' critical thinking skills in mathematics with respect to service year.

Table 5: Descriptive statistics and ANOVA test for the responses of in-service mathematics teachers enhancing students' critical thinking skills in mathematics with respect to service year

Components	Service year	N	M	SD	F	p
Teaching self-reflection and self-evaluation about thinking processes	Short	38	3.9254	.59741	.556	.576
	Average	32	3.8281	.66192		
	Long	32	3.7708	.61164		
Teaching the initial and rehearsal strategies for complex tasks	Short	38	3.8289	.66156	.424	.656
	Average	32	3.7500	.62504		
	Long	32	3.6875	.64306		
Questioning strategies in enhancing critical thinking	Short	38	3.9098	.48522	.018	.983
	Average	32	3.8839	.59672		
	Long	32	3.9063	.74152		
Enhancing students' critical thinking skills in Mathematics	Short	38	3.8892	.49065	.302	.740
	Average	32	3.8240	.52727		
	Long	32	3.7944	.56121		

From Table 5, the descriptive statistics showed that the mean response values of the mathematics teachers of short teaching service year had the highest responses on teaching self-reflection and self-evaluation about thinking processes, teaching the initial and rehearsal strategies for complex tasks, questioning strategies in enhancing critical thinking, and enhancing students' critical thinking skills in mathematics; and the mathematics teachers of long teaching service year had the least responses on teaching self-reflection and self-evaluation about thinking processes, teaching the initial and rehearsal strategies for complex tasks, and enhancing students' critical thinking skills in mathematics; whereas the mathematics teachers of average teaching service year had the least responses on questioning strategies in enhancing critical thinking. Table 5 of the ANOVA test indicate that F-values were not statistically significant between the service year groups for teaching self-reflection and self-evaluation about thinking processes($F_{(2,\ 99)}$ = .556, $p > .05$), teaching the initial and rehearsal strategies for complex tasks($F_{(2,\ 99)}$ = .424, $p > .05$), questioning strategies in enhancing

critical thinking($F_{(2, 99)} = .018$, $p > .05$), and enhancing students' critical thinking skills in mathematics($F_{(2, 99)} = .302$, $p > .05$). These indicate that the mathematics teachers ofshort, average and long teaching service year had nearly similar responses on the variables teaching self-reflection and self-evaluation about thinking processes, teaching the initial and rehearsal strategies for complex tasks, questioning strategies in enhancing critical thinking, and enhancing students' critical thinking skills in mathematics.

Multivariate MANOVA

Below is the analysis for the fifth research question ‘Is there significant interaction effect between program, level of teaching and service year on the component variables of enhancing students' critical thinking skills in mathematics?’All assumptions of MANOVA were checked. The first assumption is the observations are independent, since each person's scores are independent of every other person's scores. The second assumption is satisfying multivariate normality, since the Levene’s test is not significant it indicates that the variances of each variable are equal across groups. The last assumption is homogeneity of covariance, since from the Box’s test of equality of covariance the variances for each dependent variable are approximately equal in all groups and covariances between pairs of dependent variables are approximately equal for all groups. Therefore, the GLM Multivariate procedure provides an analysis for main and interaction effects with the four dependent variables such as teaching self-reflection and self-evaluation about thinking processes;teaching the initial and rehearsal strategies for complex tasks;questioning strategies in enhancing critical thinking; and enhancing students' critical thinking skills in mathematics. The first check we encounter was to see if correlations were too high or too low.

Table 6: Correlations of the study variables and Box's test of equality of covariance

Variables	Correlations				Box's M	F	df1	df2	P
	1	**2**	**3**	**4**					
1. Teaching self-reflection and self-evaluation about thinking processes	1	.590*	.445*	.794*	64.764	1.129	48	3865.02	.252
2. Teaching the initial and rehearsal strategies for complex tasks		1	.598*	.883*					
3.Questioning strategies in enhancing critical thinking			1	.842*					
4.Enhancing students' critical thinking skills in Mathematics				1					

* p< 0.05

From Table 6, the correlations of ‘enhancing students' critical thinking skills in mathematics’ with the other three sub-component variables are high, which are greater than .79 each. Therefore, the variable ‘enhancing students' critical thinking skills in mathematics’ were eliminated. The second test we encounter is to see the Box's test of equality of covariance matrices. This tests whether or not the covariance among the three dependent variables are the same for the two programs, three level of teaching, and three service year levels. Since the largest master in service teachers (N = 63) is 1.62 times larger than the smallest PGDT in service teachers (N = 39), we should look at the Box test, which is not significant (p = .252). Thus, the assumption of homogeneity of covariance is not violated; therefore, Wilks’ Lambda is the best Multivariate statistic to use. Thus Table 7 indicates multivariate tests for the three dependent variables.

Table 7: Multivariate tests for the three dependent variables

Source	Wilks's Lambda	F	*Df*	*Error df*	*p*	*Partial eta*^{2}
Intercept	.032	878.87	3	88	.000	.968
Program	.993	.199	3	88	.897	.007
Level of Teaching	.991	.136	6	176	.991	.005
Service Year	.980	.304	6	176	.934	.010
Program×Level of Teaching	.921	2.508	3	88	.064	.079
Program×Service Year	.998	.175	6	89	.945	.060
Level of Teaching×Service Year	.935	.671	9	214.32	.735	.022
Program×Level of Teaching×Service Year	.996	.165	6	89	.964	.052

The findings of the full factorial MANOVA (Table 7) yielded no significant main effect for program, level of teaching, and service year. The results further disclosed that the main effect of program (Wilks's Lambda = .993, F = .199, p > 0.05, eta^2 = .007), level of teaching (Wilks's Lambda = .991, F = .136, p > 0.05, eta^2 = .005), and service year (Wilks's Lambda = .980, F = .304, p > 0.05, eta^2 = .010) were not statistically significant. Thus it can be concluded that program, level of teaching, and service year were not significantly related with the dependent variables teaching self-reflection and self-evaluation about thinking processes;teaching the initial and rehearsal strategies for complex tasks; and questioning strategies in enhancing critical thinking. In order to further examine the between subject effect on the three dependent variables a separate analyses were conducted for program, level of teaching, and service year. Similarly, each of the interaction effects of the three independent variables on the three dependent variables were found to have non-significant effect as it depicts small effect size: program × level of teaching (Wilks's Lambda = .921, F = 2.508, p > 0.05, eta^2 = .079), program ×service year (Wilks's Lambda = .998, F = .175, p > 0.05, eta^2 = .060), level of teaching ×service year (Wilks's Lambda = .935, F = .671, p > 0.05, eta^2

= .022), and program × level of teaching × service year (Wilks's Lambda = .996, F = .165, p > 0.05, eta^2 = .052).

Discussion

Teaching self-reflection and self-evaluation about thinking processes

Critical thinking is self-directed, self-disciplined, self-monitored, and self-corrective thinking. It presupposes assent to rigorous standards of excellence and mind full command of their use. It entails effective communication and problem solving abilities, as well as a commitment to overcome our native egocentrism and socio-centrism (The Critical Thinking Community, 2013). The findings of this study on *teaching self-reflection and self-evaluation about thinking processes*, are all related to the items such as:challenging pre-existing ideas, guiding students how to do systematic inquiry, allowing them to think independently; encouraging students to reflect upon and make sense of new information; encouraging and guiding students to formulate hypotheses, speculate on consequences, guess, brainstorm, and discuss; monitoring and correcting inefficient strategies; and encouraging continuous reflection of beliefs about thinking, thinking processes, and evaluation of effectiveness that were found to beabove average. Comparing the responses with respect to program of teaching, level of teaching and teaching service year it was found that there was no significant difference in the responses of the in-service mathematics teachers on teaching self-reflection and self-evaluation about thinking processeswith respect to program, teaching service year; but preparatory teachers response significantly and negatively deviated from secondary mathematics teachers in teaching self-reflection and self-evaluation about thinking processes. The result is supported by Atkinson & Hunt (2008), Hunt & Touzel (2009), Mollborn & Hoekstra (2010) and Pedersen (2010) who suggested that one approach of improving student outcomes has been generating critical and reflective thinking skills among students; Mansoor & Pezeshki (2012) also showed that in applying critical thinking in school settings, it

is necessary to develop thinking skills because people who think critical would be able to understand the logical connections between ideas, construct and evaluate arguments, detect common mistakes in reasoning and solving problems systematically.

Teaching the initial and rehearsal strategies for complex tasks

Instructional strategies that employ students' higher-order thinking skills lead to improved critical thinking skills (Wong, 2007). Problem solving, heuristic teaching, problem-based learning, inquiry-guided learning methods encourage students to learn, discover, understand, or solve problems on their own, as by experimenting, evaluating possible answers or solutions, or by trial and error and improve student performance. The findings of this study on *teaching the initial and rehearsal strategies for complex tasks*, are all the component of the items such as:including individualized options in lesson plans designed to teach higher order thinking; teaching how to preview, question, read, reflect, recite, and review when learning from written materials; providing instruction in abstracting, analyzing, outlining, summarizing, and generalizing; emphasizing broad problem-solving strategies, algorithms, or heuristics; providing practice for routines of different strategies, algorithms, and heuristics until they are over learned; and teaching specific learning strategies by talking about the strategy, modelling it while thinking out loud, and providing opportunities for practice which were found to be above average. Comparing the responses with respect to program of teaching, level of teaching and teaching service year, the results revealed that there was no significant difference in the responses of the in-service mathematics teachers on teaching the initial and rehearsal strategies for complex taskswith respect to program, level of teaching, and teaching service year. The result is supported by M˘arcut (2005) who showed critical thinking and problem solving go hand in hand, that is in order to learn mathematics through problem solving, the students must also learn how to think critically; the Dictionary.com (2007) also found that h*euristic teaching*

methods encourage students to learn, discover, understand, or solve problems on their own, as by experimenting, evaluating possible answers or solutions, or by trial and error. In a similar study Gurses, Acikyildiz, Dogar, & Sozbilir (2007) suggested *problem-based learning activities* promoted critical thinking and problem-solving skills; active participation in the learning process including self-direction, identification of own learning needs, teamwork, creative discussion, and learning from peers; and the integration and synthesis of a variety of knowledge; and a study conducted by Garret et.al (1976) also showed that *inquiry teaching and learning* showed a lot of positive impact in stimulating students' thinking skills, allows students to participate actively in solving problems or answering questions posed by teachers.

Questioning strategies in enhancing critical thinking

According to Paul (1985) thinking is not driven by answers but by questions, the driving forces in the thinking process are the questions. When a student needs to think through an idea or issue or to rethink anything, questions must be asked to stimulate thought. When answers are given, sometimes thinking stops completely. When an answer generates another question then thought continues. Teachers need to ask questions and design learning experiences to turn on students' intellectual thinking engines. Students can generate questions from teachers' questions to get their thinking to move forward. The findings of this study on *questioning strategies in enhancing critical thinking*all the component of the items such as asking questions of all students equally, calling on non-volunteers as well as volunteers; asking questions about paradoxes, dilemmas, and novel problems and approaches; encouraging students generate their own questions about topics; starting with lower-order questions, remediating as needed, and lead up to higher-order questions; providing wait time after a question because students differ in the rate at which they respond; preparing questions that go beyond simple recall of factual information to focus on advanced levels of comprehension; and diagnosing students'

existing schemata by asking probing questionswere all above average. Comparing the responses with respect to program of teaching, level of teaching and teaching service year the results showed that there was no significant difference in the responses of the in-service mathematics teachers on questioning strategies in enhancing critical thinking with respect to program, level of teaching, and teaching service year. In the support of the result,Haynes and Bailey (2003) emphasized in their research the importance of asking the right questions to stimulate students' critical thinking skills, and other researcher Hemming (2000) also focused on integrating questioning techniques into class discussions to support an educational environment where students can demonstrate and practice critical thinking skills.

Enhancing students' critical thinking skills in Mathematics

Critical thinking requires a systematic approach that affords students an opportunity to skilfully evaluate information and reach the most favourable solution to a problem based on the known research (Shah, 2010; Thompson, 2011). The assignment presented asked the students to use critical thinking skills to solve the problem of what and how to implement evidence-based practices for a specific prison population. For this study the aggregate average value of all the items of '*enhancing students' critical thinking skills in mathematics'* was found to be above average. Comparing the responses with respect to program of teaching, level of teaching and teaching service year the results showed that there was no significant difference in the responses of the in-service mathematics teachers on enhancing students' critical thinking skills in mathematics with respect to program and teaching service year; but preparatory teachers response significantly and negatively deviated from secondary mathematics teachers in enhancing students' critical thinking skills in mathematics. There was no interaction effect between program, level of teaching and service year on the component variables of enhancing students' critical thinking skills in mathematics. In line with the above result, Watson &

Glaser (1980) explained that critical thinking plays an important role in many kinds of occupations, particularly those in which careful, analytical thinking is an essential part of the job; and in the education system, Stacey (2008) suggested mathematical thinking is important in three ways: It is important as a way of learning mathematics; important for teaching mathematics; and an important goal of schooling.

Conclusion and Recommendations

Conclusion

This study revealed that the perception of mathematics teachers on teaching self-reflection and self-evaluation about thinking processes, teaching the initial and rehearsal strategies for complex tasks, questioning strategies in enhancing critical thinking, and enhancing students' critical thinking skills in mathematics were all above average. Yet, the perception of teachers towards teaching the initial and rehearsal strategies for complex tasks, and questioning strategies in enhancing critical thinking did not differ between teachers teaching at different levels – primary, secondary and preparatory which seeks further investigation. Service year did not account to bring variation in the perception of teachers towards the variables of investigation, standing against the theory of experiential learning that vows service year accounts to better practice and capability. Despite these, there significant difference observed in an interaction effect of program and level of teaching on the dependent variables of teaching self-reflection and self-evaluation about thinking processes, and teaching the initial and rehearsal strategies for complex tasks appeals further investigation. To this end, emphasis should be given to: challenging the pre-existing ideas by presenting situations that students are unable to explain-paradoxes, dilemmas, and perplexities; monitoring and correcting inefficient strategies; including individualized options in the lesson plans designed to teach higher order thinking; providing practices for routines of different strategies, algorithms, and heuristics until they are over learned; and asking questions about paradoxes,

dilemmas, and novel problems and approaches. On top of these, preparatory teachers had problems in enhancing students' critical thinking skills in mathematics which may be caused due to implementation of more of lecture method, or they didn't gave opportunities for the students to do mathematics in the classroom. Master trainees of the preparatory teachers had problems in teaching self-reflection and self-evaluation about thinking processes, and teaching the initial and rehearsal strategies for complex tasks; and PGDT trainees of the primary teachers had problems in teaching the initial and rehearsal strategies for complex tasks. These and the significant variation observed by program level accounted to level of teaching seeks further investigation to unpack variables that accounted to the overall teachers' perceptions and practices in enhancing critical thinking skills. Teachers trained in the master program are expected to teach at the preparatory, but those master program in-service teachers were found to have better perception when they teach at primary which they are not be trained for and this seeks further investigation.

Recommendations

Based on the findings of the study, the following recommendations are forwarded: It is expected that as level of teaching increases, teachers ought to have better capability of implementing informed actions. But, the results from this study did not reveal to significant difference among teachers teaching at different levels. Hence, training should be given to preparatory teachers and master trainee teachers on enhancing the students' critical thinking skills, teaching self-reflection and self-evaluation about thinking processes, and teaching the initial and rehearsal strategies for complex tasks, for better account and provision of opportunities for their learners. Training should also be given to PGDT trainee teachers in teaching the initial and rehearsal strategies for complex tasks at which they were found to be lagging. Teachers should focus on challenging pre-existing ideas; monitoring and correcting inefficient strategies; including individualized options in

lesson plans designed to teach higher order thinking; providing practices for routines of different strategies, algorithms, and heuristics; and asking questions about paradoxes, dilemmas, and novel problems and approaches. The variation in the perception of teachers in the in-service program teaching at primary and preparatory; and that of program of study and the level of teaching demands further investigation as to why the master program teachers have better perception when they teach at primary which they are not be trained for, and otherwise.

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