

Factors Determining Mathematics Performance of High School Students: Implications for Teacher Education

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Abstract The alignment between the goals of pre-service education and that of in-service education is important. Institutions which offer a degree in education must constantly connect and understand the experiences of the teachers and learners in the elementary and secondary schools so that they can offer better undergraduate programs. This study explored how critical thinking skills of secondary students contribute to their Mathematics performance. There were 236 secondary student participants in this study from a private high school in Mindanao, Philippines. Correlational design was utilized in this study. A questionnaire was used to gather data on critical thinking skills of the students. The questionnaire has undergone Rasch analysis with reliability indices of .88 (high) for Part 1 and .77 (moderate) for Part 2 thus establishing preliminary evidence of construct validity. Using path analysis, the model showed that critical thinking skills significantly explained the Mathematics performance of the participants. The results called for a need to address the teaching of critical thinking skills among secondary students because this will benefit the facilitation of better Mathematics performance. Critical thinking skills must be taught alongside Mathematics content. Teachers carry out multiple roles of delivering the content at the same time honing the critical thinking skills of the students. Undergraduate education specifically for teacher education has an important role to play in preparing future teachers on how to develop critical thinking skills of their students. It is a two-way task of developing future teachers to be critical thinkers and teaching them how to teach such skills to their students so that when they are in the field of teaching, they teach both content and critical thinking skills.

Keywords: *critical thinking skills, teacher education, math education, Rasch analysis, performance in Mathematics*

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1. Introduction

Mathematics has always been one of the important subjects in school. It is one of the core subjects as identified by the Department of Education. Mathematics pervades through life [1]. In fact, in the 21st century where information and technology are advancing, one's knowledge and skill in Mathematics can contribute towards the development of an individual and of the country's progress. Mathematics education is important as it can be a tool for studying other disciplines, a style of thinking, and a vehicle for problem solving, critical thinking and sound judgment. Hence, Mathematics must be learned with depth which can be achieved through development of critical thinking skills. However, literature on the influence of critical thinking to mathematics performance is limited.

The educational system of the Philippines has undergone major reforms to improve Mathematics education. In 2013, the Enhanced Basic Education Act paved the way to Philippine K to 12 Program. The K to 12 curriculum

emphasized problem solving and critical thinking as twin goals of Mathematics education [1]. While substantial efforts had been made for secondary mathematics to be taught well in a certain private university, the results in the standardized achievement test provided by an established test provider did not meet the expectations. These results led to the investigation of the factors that might predict mathematics performance. This research aimed to explore the interplay of admission test results, grades in their English language subject, critical thinking, and their influence on Mathematics performance in the achievement test using path analysis.

2. Literature Review

2.1. Entrance Exams

School admissions through entrance exams had been in place for quite a long time to identify which students are to be accepted. The students' college entrance exam results were found to be a highly significant predictor in collegial academic performance based on the general point

average [2]. However, House [3] revealed that admission test scores were significantly related to achievement in Chemistry, Philosophy, Sociology and Psychology courses but not on Mathematics. It is then important to determine whether the entrance exam scores of students say something about future Mathematics performances to provide a space of revisiting this important requirement during admission. These high school students upon entering their first year in secondary education had to pass an entrance examination. The scores for this examination were examined if this requirement predicts the Mathematics achievement of the students. The study of Papenhausen [4] reported that entrance test scores are not the best predictors of student success, but it is important that they also must be taken into consideration.

2.2. English Language

Teachers often comment on some students who succeed in working basic operations in Mathematics but fail to give a valid and convincing reason or proof on how they arrive at their answers. Results of various studies have shown that English language is a significant factor in predicting Mathematics performance [5,6,7]. Language is the primary instrument of thought; thinking, learning and language are interconnected, and such has an essential role in all learning areas. Students struggle with word problems in Mathematics because they cannot understand the problem well enough to see the underlying Mathematics problem. Brown [7] argued that English language learners (ELL) find Mathematics such a difficult subject due to language barrier. Mathematics becomes the "third" language. It becomes a greater challenge as students attempt to learn and understand the cognitively demanding and highly abstract Mathematics concepts, Mathematics vocabulary, and syntax while still struggling how to understand English language. Garcia [8] studied the relationship of English and Mathematics competency of college freshmen students in a selected school in the Philippines and found out that English proficiency accounted for a 26.4% variance on the Mathematics competency of the respondents. Garcia identified the predictors as grammar, vocabulary and reading comprehension. Among these predictors, grammar had the largest effect on Mathematics competency followed by vocabulary and the last is reading comprehension. There are more studies showing how the English language predicts Mathematics performance among varied groups. English proficiency is reported as a statistically significant predictor of Mathematics scores among Grade 3-5 English language learners. Mathematics scores increase simultaneously with English proficiency [9].

2.3. Critical Thinking Skills

John Dewey [10] believed that educators have an important role to develop critical thinking in each student; to question and seek evidence to guide them in favor or against what they previously believed to be true. Critical thinking skills are one of the higher order thinking skills (HOTS) that teachers want their students to demonstrate. Forsythe-Newell [11] argued the need to revitalize critical thinking skills in schools because of its value on society.

If critical thinking is developed in school, students will become more active learners, will ask intelligent questions, will interpret facts, challenge ideas and arguments, and become responsible for their understanding. If the students are not exposed to critical thinking, they cannot do challenging mathematical problems [5] that may involve deductive reasoning, classification, and inferential reasoning. Janubas [12] cited Reuyan who concluded that students' critical thinking skills have a significant effect on their mathematics achievement test. The studies of Tanujaya, Mumu and Margono [13] showed that critical thinking skills of students have a significant positive correlation with their academic performance in Mathematics instruction. Chukwuyenum [14] added that critical thinking skill was also a helpful tool in improving students' understanding of Mathematics concepts. Furthermore, Alcantara and Bacsa [15] reported that mathematics performance of the students is positively correlated to their level of critical thinking skills and problem-solving skills.

Research on the factors that influence achievement students in Mathematics is essential in the field of education. Notably, the present study focuses on English language, entrance exam results and critical thinking skills. Specifically, it sought to answer the following question:

What model would best fit the structure of students' Mathematics performance in the standardized achievement test? Upon getting the results of this study, the researchers hoped to have an answer on what areas best explain Mathematics performance so that this factor will be further analyzed and strategies can be crafted to facilitate success of students in Mathematics.

3. Methodology

The study used descriptive - correlational design. It addressed the questions on the level of the respondents' achievement mark in English and Mathematics, the level of the respondents' critical thinking skills, the level of the respondents' performance in the standardized achievement test without manipulating any variable. The study employed path analysis to test the fit of the hypothesized model (Figure 1). The model argued that English language grade, entrance exam result and critical thinking skills have either direct or indirect influence on mathematics performance. Developed by Sewall Wright, path analysis is used to provide estimates of the magnitude of effect and significance of hypothesized structural model through a pictorial representation called path diagram [16]. A path diagram portrays the correlations among variables, the directions of those correlations and the "paths" along which these relationships travel. In this study, path analysis was used to test the priori model using the data from two hundred thirty-six ($n = 236$) Grade 8 respondents from a private junior high school in the Philippines. Stratified random sampling was done among the eleven sections. Ethics considerations were strictly followed in the entire duration of the research especially in data gathering procedure, anonymity and confidentiality.

The hypothesized structural model shows the path of influence of the exogenous variables and endogenous variable on Mathematics Performance on the Achievement Test. Entrance Exam Result and English Language Grade

were positioned as exogenous variables with paths leading to Critical Thinking and Mathematics Achievement. Critical Thinking was treated as an intermediate variable with a path predicting Mathematics Achievement.

We checked variables to ensure that assumptions of normal distribution, outliers, multicollinearity, and equality of variance were met.

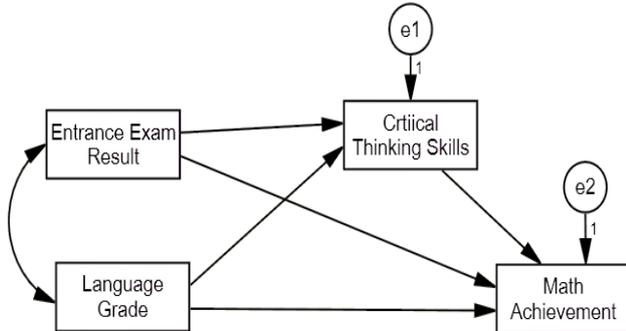


Figure 1. Hypothesized structural model Entrance Exam Result, English Language grade, Critical Thinking Skills towards Mathematics Achievement

3.1. Participants

A total of 236 Grade 8 junior high school students from a private sectarian co-education school participated in the study. These participants were chosen from eleven heterogeneous classes through stratified random sampling. The sample size was determined through Cochran’s sample size formula for finite population. Participation was voluntary and not compensated. Permissions were acquired as this study was conducted. Ethical guidelines were observed in the conduct of this study.

3.2. Measures

This study made use of secondary data namely, Entrance Test Result, English Language grade, and Mathematics Achievement Test Result. The primary data were obtained from the Critical Thinking test. The Critical Thinking test was developed according to the Grade 8 learning competencies provided in the Department of Education K to 12 Curriculum. The questionnaire and the table of specifications were further verified for content validity by two veteran and expert Mathematics teachers of the school. The test consisted of two parts: Part I is a twenty - three item multiple -choice test; Part II is a twelve item production/constructed-response test. The test has 47 points where each item in part I is worth 1 point while each item in part II is worth 2 points. A pilot test was conducted to a group of 40 students for part I and another group of 34 students for Part II. Then the test was subjected to construct validity and reliability using Rasch analysis.

The statistics generated by Rasch analysis indicated that the item reliability indices of the tool are 0.88 (high) and 0.77 (moderate) for Part I and Part II respectively. Furthermore, Rasch analysis was used to establish preliminary evidence of construct validity [17]. The validity of the tool is examined through the item fit statistics, which evaluate the extent to which items are tapped into the same construct.

MINISTEP® (WINSTEPS®) Version 3.81.0 was used to conduct Rasch analysis. It is a free evaluation, student, trial and demonstration version is a reduced version of WINSTEPS [18,19]. The freeware can be downloaded from <https://www.winsteps.com/ministep.htm>

4. Results and Discussions

The respondents have a fair critical thinking skill as indicated by the mean of 966.02. Majority (92.86 percent) of the respondents have fair critical thinking skills. Whereas only very few students (7.14 percent) have good critical thinking skills. The students were able to supply their responses to the Part 1 since this part is multiple-choice, yet the mean score in Part 1 is only 473.53 as compared to the subtotal measure of 937.55, this measure is at the fair level of critical thinking skills. As for Part 2, none of the students was able to finish. A very large fraction of the respondents did not reach most of the items in Part 2 of the critical thinking test. Starting with the very first item in part 2, the number of respondents who did not reach the succeeding items was significantly increasing.

After testing the priori model with the data set and removing the non-significant path from Entrance Exam Result toward Mathematics Achievement, the final path model is achieved (Figure 2). This model has a comparative fit index of .991 and adjusted goodness of fit index of .953 which are considered good fit; its root mean square error of approximation of .073 is considered an acceptable level of error [20]. These indices imply that the resulting path model regarding Mathematics Achievement adequately fits the observed data from the 236 samples in this study.

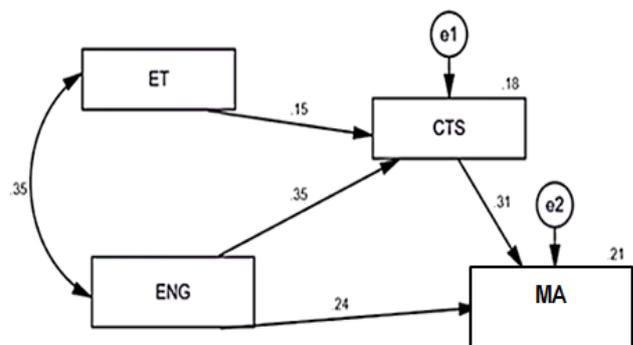


Figure 2. Final model for Entrance Exam Result (ET), English Language grade (ENG), Critical Thinking Skills (CTS) towards Mathematics Achievement (MA) (Model Fit Indices: CFI = .991 AGFI = .953 RMSEA = .073)

All paths in this model are highly significant ($\alpha < .01$) except for the path coming from entrance exam result to critical thinking skills ($\alpha = .016$). Considering the fit indices, the resulting path model adequately fits the observed data from the sample of Grade 8 students. It can be seen in the model that the entrance exam result contributes an indirect effect on Mathematics achievement through critical thinking skills. The ET taken by the students covered competencies in arithmetic. Although arithmetic is fundamental to Grade 8 Mathematics, a student’s commendable performance in

the Entrance Test does not guarantee a high achievement in Mathematics. On one hand, English language grade has both an indirect through critical thinking skills and a direct effect on Mathematics achievement. This confirmed the result found out by Rashid and Hashim [22] which indicated that language had a significant direct positive effect on critical thinking.

Analysis showed that critical thinking significantly explains Mathematics performance. Among the three independent variables, critical thinking skills is the greatest predictor of Mathematics achievement ($b = .31$). The standardized beta weight means that for every one standard deviation increase in critical thinking skills, Mathematics achievement increases by .31 standard deviation.

Our resulting model confirmed the literature suggesting that critical thinking has a significant effect on Mathematics achievement. Critical thinking empowers students to do challenging Mathematical problems [5,13,21]. The standardized test was constructed using the Revised Bloom's Taxonomy of Educational Objectives which included higher order level of thinking skills such as analysis, evaluation and problem solving. This suggests that students who are critical thinkers may also be particularly good at navigating standardized tests. We are however left to speculate about the Mathematics achievement if the critical thinking of the respondents had been better than just fair.

5. Implications for Teacher Education

The main finding of the study points to the importance of developing critical thinking among secondary students. This paper argues that critical thinking skills are highly essential for students to perform well in Mathematics and the results for critical thinking need to be addressed. Critical thinking skills have to be taught side by side with the teaching of content. For example, students taking a degree in Education with a focus on Mathematics education must also learn the various strategies of developing critical thinking skills alongside learning the Mathematics skills and concepts. This is essential so that when a pre-service teacher will go to the field and teach, aside from teaching content only, he or she will also teach students how to think critically.

There are two important implications from this study. First is on the development of critical thinking skills among the secondary students and second is the development of these skills among teachers who are teaching Mathematics. Teachers have to be aware that as they teach the subject matter, they also must at the same time implement strategies to promote the critical thinking skills of the students. Critical thinking skills have to be integrated into teaching content in Mathematics. Jackson, [23] in his paper explained the importance of increasing critical thinking skills to improve the ability of students to solve problems in Mathematics. Students who were taught to think critically at an early phase can transfer their learning to other courses or lessons.

The result tells us that the teachers must think of creative ways to develop the students' critical thinking skills. But if we want our students to be critical thinkers,

teachers and future teachers must first be critical thinkers themselves. One cannot give what he or she doesn't have. The level of the teacher's critical thinking influenced how the teacher designed his or her instruction [24]. There is an obvious challenge for teacher educators and for teacher education institutions to train their students to teach critical thinking. Teachers go to the classrooms to teach content however it is also crucial that aside from teaching the subject matter, students are also taught how to think critically, how to analyze situations and make sound evaluations. Teachers should not confuse critical thinking with intelligence. Critical thinking can be taught and reinforced in everyone in all ages [25]. Equipping pre-service teachers to be knowledgeable in their field of specialization does not guarantee their skills to stimulate critical thinking skills of students. Teaching critical thinking has to be incorporated as pre-service teachers are being trained in different teacher education institutions. Despite this postulate, Reed and Kromrey [26] pointed out that although literature suggests to strengthen critical thinking skills among students, most often they are just theoretical and are not integrated in the curriculum. This is a call of challenge among teacher education institutions. Willingham [27] said that the ability to think critically depends on having adequate content knowledge and practice. Hence, adequate opportunities should be provided for pre-service teachers to develop or reinforce critical thinking. Often students are fed with information and procedures without deep understanding and reflection.

Critical thinking according to Ennis [28] is reasonable and reflective thinking that is focused on what to believe or do. Critical thinking does not rely on step-by-step procedures. Critical thinking can be taught by embedding it in the course and may not be taught as a separate subject. There are a lot of courses in teacher education where the pre-service teachers could be trained for higher order thinking skills like assessment courses and classroom management courses.

John Dewey [10] believed that educators have an important role in teaching students to question and seek evidence to guide them in favor or against what they previously believed to be true. Critical thinking is a questioning attitude before accepting or rejecting ideas, arguments, or beliefs [29]. Critical thinking then can be reinforced by allowing pre-service teachers to ask questions, challenge ideas, and explore the rich possibilities through meaningful and engaging discussions. Teacher educators can do this through reflective teaching. Halpern as cited in Wang and Zheng [29] agreed that teachers can do something to enhance critical thinking skills for everyone and every class. But teacher educators who are constrained to didactic approach for whatever reason limit the space for the development of critical thinking.

While critical thinking is teachable [29], it does not transfer from one subject to another unless being learned there [30]. Success in teaching critical thinking depends on parallel efforts and alignment in the curriculum. Teacher educators training future teachers have to articulate the teaching of critical thinking as they plan their lessons and as they craft their syllabus. The vital concern is how to effectively teach the courses in order to maximize the transfer of such skill. Since this is a skill, it

has to be practiced, applied and evaluated. This valid concern requires teacher educators to be expert in their discipline and then lead students to see the links or integrate with other disciplines. This can be achieved through the concerted efforts of the entire teacher education institution. Once learning outcomes are identified, learning activities and assessments must be designed that allow development of critical thinking skills. Educational practice should be looked seriously into. Part of this study is the implementation of some strategies that promote critical thinking in mathematics.

5.1. Accountable Talk

One of the practices that can be utilized is accountable talk. Accountable talk goes beyond expecting students to give the correct answer to a question posed by the teacher. With careful planning and modeling, the students argue among themselves towards understanding [31]. In this strategy, the teacher carefully plans and models the norms of argumentation such that clear standards of what is considered good discussion are set for the entire class. These standards are often described as “three accountabilities:” accountability to knowledge (finding the truth), accountability to reasoning (providing evidence), and accountability to community (showing respect towards others) [31]. In Accountable talk, every student is given the opportunity to be heard as he or she agrees, disagrees, builds on a classmate’s (or teacher’s) ideas, challenges a claim, reflects upon their own reasoning; proposes alternative solutions or explanations.

In one of teacher education courses, entitled, Teaching Mathematics in Primary Grades, each pre-service teacher was asked to conduct a microteaching of an assigned mathematics topic. As one conducts the teaching, the other classmates assume the role as pupils. After the microteaching, everyone takes turns in giving their comments as to the success of the microteaching in terms of concept development, use of theories of learning, and their suggestions how they would modify the lesson if they were to do it themselves. Prior to this discussion, the class was given guidelines and prompts how to start and give feedbacks. At the end of the semester, these pre-service teachers were asked to present a portfolio of their learning in the course. One of the instructions was to identify a course activity that developed their critical thinking and communication skills. All of them identified the Accountable talk to have developed their critical thinking and further explained how.

When these thinking processes are developed in the students, we are teaching them to be critical thinkers. Ennis believes that critical thinking is reasonable and reflective thinking that is focused on what to believe or do and does not rely on step-by-step procedure. This strategy allows critical thinking to be embedded in the course whereby students own the process of reasoning and conclusion based on evidence. The National Council of Teachers of Mathematics (NCTM) suggests using productive discourse to make sense in math where students explain and defend their solution and agree or criticize others’ solution. They can share how their ideas are related or different from others. In this way, students are given opportunities to make meaning of ideas and own

them as well. When pre-service teachers learn this skill in their undergraduate courses, they can in their future classes create the same atmosphere where students will not only memorize the steps of the solution. Instead, will ask intelligent questions, interpret facts, challenge ideas and arguments and become responsible for their own understanding. Our schools will have teachers who know how to elicit critical thinking. Accountable talk can be a good strategy to actualize this goal.

5.2. Cooperative Learning

Cooperative learning approach is another strategy that can facilitate critical thinking [32,33] through communication and interactions. Pre-service teachers should be exposed to different types of cooperative learning strategies and how to effectively use them in order to meet the five basic elements of cooperative learning namely, positive interdependence, individual and group accountability, face-to-face promotive interaction, and group processing. How to organize cooperative learning groups and designing effective means to monitor and track individual student learning are also essential to the success of cooperative learning approaches.

The pre-service teachers need to be trained and exposed to case analysis and avenues where they can think, analyze and make judgment. It is also necessary that their language skills have to be developed so that they can communicate well the message to their students.

Teacher education in the undergraduate level has a highly important role in the development of the critical thinking skills of its pre-service teachers. Undergraduate programs for the training of future teachers have to establish programs that would offer the integration of concrete strategies for the development of critical thinking skills. Since critical thinking is a skill, it needs repetition for it to be strengthened. Programs that would motivate students like case analysis. This study opens another research problem of doing action research to really see whether students are exposed to pre-identified strategies (case analysis, Accountable talk, etc.). Educators would argue that students must critically think however, the teaching of this skill is not so much given attention because teachers are busy to cover content. If students are best known for their communication skills by asking them to communicate, speak and write, it is of the same argument for critical thinking skills. Students are best known if they can think critically if they are given scenarios to demonstrate such skill and this can be done consistently.

6. Conclusions and Recommendations

This study supports Bronfenbrenner’s Ecology of Human Development which argued that a learner’s development is a result of interactions between the individual and the different ecological systems he is in. The mathematics performance in the standardized achievement test is a result of interplay among the factors considered in this study, whether directly or indirectly.

Based on the findings and implications of this study, it is recommended that teacher education institutions

scaffold and implement activities that will improve students' critical thinking skills alongside learning the Mathematics skills and concepts. The teaching of critical thinking skills have to be given due priority in teacher training institutions so that teachers are not just competent in conveying and explaining content in Mathematics but facilitate the deeper understanding of such concepts.

Future researchers may conduct longitudinal study on how these pre-service teachers eventually develop critical thinking skills in the internship and on-the-job training.

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This is to note that Dr. Delosa and Dr. Ong are co-authors.

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