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Technology Exposure, Attitude and Mathematics Achievement: A Structural Equation Model for Comparing Control and Expose Group of Students

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Abstract
A research regarding mathematics performance of students via technology exposure was unraveled through a relation between students' attitude towards mathematics and technology. This approximation of linkage was researched using statistical tests through structural Equation Model (SEM) and Latent Class Analysis (LCA). Hypothetical results of the existing difference between the control group and the exposed were proven through a technic known as an integrated model within the Mplus® software package. The results showed significantly that students from the exposure group have better performance than the control group. Besides that, there was a dramatic improvement of students from less critical courses. Students' priority on mathematics and technology plays an important role as a mediator for background variables and students' mathematics improvement.
Keyword: technology exposure, structural equation modeling, latent class analysis, mathematics achievement

Introduction

A person's ability to translate success based on attitude towards subjects such as mathematics has become a conversation topic of every researcher. Most students choose to aim for better success to actualize the meaning of life as a student (Quaglia & Cobb, 1996). These days, it is a question in every researcher's mind; why is it that the variable of attitude towards subjects especially mathematics has become so important in the performance of a student? It is also said that attitude plays an important role in affecting learning method, direction decision after graduation, increase of motivation in academics and performance in learning (Kharuddin et al., 2019). Roughly, the role of attitude is that great in determining one's future success. Therefore, can it be concluded that the relation between students' performance can be improved through attitude towards subject that is being learned? Earlier research has shown that the home and school environment play important roles in attitude development towards a subject (Quaglia, 1996).
This research also relates several other latest factors to influence students' attitude towards mathematics especially students at the pre-university level. In the education of mathematics, three important aspects influence the lives of students to guarantee a more excellent life in the future. They are the ability to show a whole interest (Doerr & Zangor, 2000), directness to achieve success

(Quaglia & Cobb, 1996) and something new exposure towards students (Allison et al., 2002). In these researches, the three mentioned aspects are referred to as technology exposure, attitude towards mathematics and performance in mathematics (Kharuddin et al., 2017). The intercorrelations of these three variables in these past researches have been less emphasized. Therefore, the researcher chooses to use the integrated model from the Structural Equation Modelling (SEM) and Latent Class Analysis (LCA) to analyse measurement error sufficiency among the variables besides simultaneously detecting estimation based on students' classification according to attitude and technology. Besides that, the students' background effects are also to be taken into account (Pascarella et al., 1996) in order to control existing direct and indirect effects towards the students' mathematics achievement in the pre-university level (White & Mitchelmore, 1996).

Meanwhile, for the technology exposure variable, a learning aid of the latest technology known as the Graping Calculator (GC) is introduced to a target group. There are two groups involved in the variables and that is the control group and the exposed group. Students in the control group are not formally exposed to the GC utilization. This group will have a traditional approach towards learning where they are only allowed to solved mathematical problems with pen and paper with the aid of a typical scientific calculator. As information, until lately (year 2014), Malaysia's math education allows the use of scientific calculators from middle secondary level up to the higher tertiary education level (Tajudin et al., 2009). On the other hand, the exposure group was generally introduced to the function of graphing calculator beforehand (Kharuddin et al., 2017). They were thought how to interact with the GC in order to solve mathematical problems in this advanced application. Certainly, where are also given a sufficient period of time to get used to the GC application.

Literature Review

The importance of setting performance target was earlier translated and suggested by Lewin & Dembo (1931), where performance level determination, identification of factors affecting the rise and fall and the relation to students' attitude was detailed clearly. Meanwhile, Lewin et al. (1994) proved that attitude itself has a special relation to success achievement besides prevention of failure. Subsequently, research by Sewell & Hauser (1975) in research involving a group of male students from a large and longitudinal sample verified that students' background plays an important role in math performance although the success achievement ability is constant. Accomplishment or mathematical score can be concluded as a student's achievement capability specifically in the subjects of math. In the research, the factor of formal exposure to technological aid is also accounted to identify students' capability towards technology in determining their math achievement. Upon obtaining data, students' scores were recorded as continuous and a normality test was done.

The obtained data are not normally spread and a standard transformation shall be conducted. Standardized scores are recorded as Standardized Mathematics Achievement with GC-Aided (SMAWGA). Uniquely, this research is placed upon technology exposure factor against math achievement or SMAWGA for science stream students of the pre-university level (Kharuddin et al., 2020). Formal exposure is concentrated on one group alone where theoretically; students whom are given exposure would achieve better math score than students without exposure (Schwalbach & Dosemagen, 2000; Slavin et al., 2009). However, there are researches proving that technology does not hold the positive effect on students' math achievement (Adya & Kaiser, 2005). This is proven after Adya & Kaiser found that student group especially males having average achievement whilst having an interest in using technology in science and math subjects. Meanwhile, female student group having excellent performance favoured the traditional method of learning, as according to them, technology impedes their minds besides cause the inability to master the real math education as a whole. Generally, students with high and excellent achievements prefer transparent and effective learning, without the so-called distraction and involvement of technology (Krisler & Simundza, 2003). For them, the existence of technology would critically hinder their thinking process and become dependent on the technology and then cause laziness in putting effort (Walker, 2008; Heirdsfield et al., 2008). This student group can be categorized as an anti-group for technology in math. They prioritize only the ability to think quickly without taking into account the capability and disadvantage of others. This group has more concerned about their own success over allowing others (Kharuddin et al., 2020). Furthermore, they are unwilling to give themselves a chance to identify the uniqueness and how advanced the technology can speed up the process of learning deeper math (Boylan & Saxon, 1998; Bendickson, 2004).

As a conclusion, there are positive and negative effects with technology exposure in math especially when students' academic background is considered. Therefore, students' attitudes towards math and technology shall be studied and emphasized. This is an approach frequently discussed in the world of math education research. However, many factors could be classified as attitude. Among them are mathematical belief, motivational effort and mathematical self-efficacy (Kharuddin et al., 2017). One added value to this research is more focus is given towards students' attitude towards GC application in math at the pre-university level. Earlier researches have mentioned several impacts on students' math achievement through the direct effect of attitude towards mathematics (ATM). However, in the latest research by Reznichenko (2007), technology along with positive attitude has a deeper effect on math achievement, especially to less potential student groups. This shows that the role of attitude in math and technology should be hand in order to have a direct effect on students' math achievement especially students at the foundation level where their future depends fully on their performance in the present level where the next level would be bachelor's degree in the field of their choice and interest.

Research Question

a) Is there an effect of the technology exposure on student's mathematics achievement with GC-aided (SMAWGA), and how is this effect mediated by student's attitude? Does this effect work directly or indirectly?
b) Do the structural equation model (SEM) fitting student's attitude and achievement differ for control and expose group taking into account other student's background variables?

Research Methodology

a) Sampling Technique

This integrated model research is named Experimental Study on Technology in Mathematics, in short ESTIMATH. This research involves 763 students in the foundation level of Centre for Foundation Studies, International Islamic University Malaysia – CFS, IIUM, batch of 2011-2013 representing 2,072 science stream student population. As many as nine subject courses were considered through the stratified sampling technique, developed by Kish (1965) and then reinterpreted by Ross (1987). This institute is a public higher education centre and what is unique is that the students are divided into fixed subject courses. Students are registered according to science courses, in a detailed manner. Hence, it is different from other public matriculation centres where students are generally registered into science courses either health sciences or physical sciences. In this case, students are not given earlier course exposure and would only decide on their bachelor's degree courses after completion of foundation or pre-university level. Is it contrary to CFS, IIUM, where students already have a preference and tendency on a future course and career from an earlier stage in the foundation level? Courses selections in this research are arranged according to priority from 1 to 9 where courses 1-3 are most critical, involving pure science streams such as medicine, dentistry and pharmacy. Meanwhile, 7-9 are physical science stream with less critical courses such as physical science, engineering and ICT. Table 1 illustrates this student crosstabulation sampling in further detail.

Table 1: Crosstabulation of Sample Size by Course Taking, Group of Technology Exposure and Sex Division

Course		Sex		Total
		male	female	
PreMedic	control	10	18	27
	expose	6	18	24
Dentistry	control	6	16	22
	expose	4	8	12
Pharmacy	control	22	40	62
	expose	8	40	48
AllHS	control	20	42	62
	expose	14	40	54
Nursing	control	4	20	24
	expose	0	20	20
BioSc	control	14	38	52
	expose	10	40	50
PhySc	control	8	14	22
	expose	8	16	24
Engine	control	48	46	94
	expose	74	62	136
ICT	control	4	10	14
	expose	4	11	15
Total	control	136	244	379
	expose	128	255	383
		264	499	763

b) Attitude Towards Mathematics (ATM) and Attitude Towards Technology (ATT) Variables

For ATM and ATT tests (Appendix A), there are 60 items or latent variable that are categorically tested using the Likert 5-point scale; starting from 1 – strongly disagree to 5 – strongly agree (Likert, 1932). By using a more detailed questionnaire adapted from Martin Fishben & Icek Ajzen (1980) and Lamb & Fullarton (2001), this research has even more meaning and effectiveness through SEM statistical tests. Analysis for statistical test in this research in whole is using Mplus® 7.0 software (Muthén, 2001; Muthén & Muthén, 2012). The software is suitable for the research as it involves unobservable variables. Theoretically, the attitude variable cannot be studied or formulized using a numerical data collection view (Awodey, 1996). Nevertheless, through latent traits, attitude can be classified into several groups and categories. This approach was tested using a statistical test known as Latent Class Analysis (LCA) to allow the researcher to study the actual attitude of students through math and technology.

c) Technology Exposure Variable

Students from the science stream at the pre-university level were experimented using group comparison technique through technology exposure variable. The students' population list is stratified according to courses and names were selected randomly, divided into two groups which are control group and expose the group. Students of the control group relearned math according to the pre-university's traditional way where the use of learning aid is limited to pencils/pens, papers and scientific calculators. After the 2-hour revision workshop, students were to sit a structural math test and supplied with graphing calculators (GC) each for the entire 1-hour test. Students were also required to indicate by marking how the questioned were answered i.e. via traditional or GC method or also both. For the second group; expose group, students were exposed to interactive GC application. A workshop was conducted to provide optimum exposure to the students on how to solve given mathematical problems aided by GC. All of the students in this group have never used nor experienced GC application before. After the end of the introduction to GC workshop, which lasted for 2 hours, students were supplied with GC emulator software to be installed on their personal computers. Students were then given one week to master the GC application with given exercises. After the end of the exercise, students are called back for a math test of a similar format and questions taken by the control group. This is to test the effectiveness of GC amongst the students and to verify the interpretation of students' attitudes towards math and technology. Consequently, results of the math tests with GC application, after transformation is recorded as variable SMAWGA.

Analysis and Results

Stage 1: Factor Analysis

This research began with factor analysis allowing 60 latent variables to be analyzed for item elimination. 15 items are from the ATT variable and the remaining 45 items are ATM variables. Table 2 shows the cut-off value for factor loading resulting from the factor analysis elimination test.

Table 2: A simple factor solution by using *Geomin rotation* and a factor *loading cut-off* of 0.3

	AG	FACTOR LOADING	MB	FACTOR LOADING	ME	FACTOR LOADING	MS	FACTOR LOADING
	A1	0.744*	B1	0.248*	E1	-0.119	S1	0.370*
	A2	0.774*	B2	0.490*	E2	0.316*	S2	0.492*
	A3	0.871*	B3	0.549*	E3	0.360*	S3	0.539*
	A4	0.844*	B4	0.388*	E4	0.530*	S4	0.614*
	A5	0.845*	B5	0.364*	E5	0.468*	S5	0.521*
	A6	0.751*	B6	0.341*	E6	0.576*	S6	0.492*
	A7	0.796*	B7	0.348*	E7	0.556*	S7	0.623*
	A8	0.756*	B8	0.344*	E8	0.229*	S8	0.642*
	A9	0.824*	B9	0.243*	E9	0.085*	S9	0.465*
	A10	0.862*	B10	0.319*	E10	0.610*	S10	0.598*
	A11	0.917*	B11	0.300*	E11	0.721*	S11	0.619*
	A12	0.880*	B12	0.123*	E12	0.732*	S12	0.533*
	A13	0.912*	B13	0.392*	E13	0.576*	S13	0.496*
	A14	0.795*	B14	0.315*	E14	0.271*	S14	0.445*
	A15	0.829*	B15	0.156*	E15	0.623*	S15	0.241*
χ^2	1090.428		1090.428		960.265		1697.063	
P-value	0.000		0.000		0.000		0.000	
RMSEA	0.121		0.121		0.113		0.153	
P-value	0.000		0.000		0.000		0.000	
CFI	0.368		0.368		0.775		0.648	
TLI	0.263		0.263		0.737		0.589	

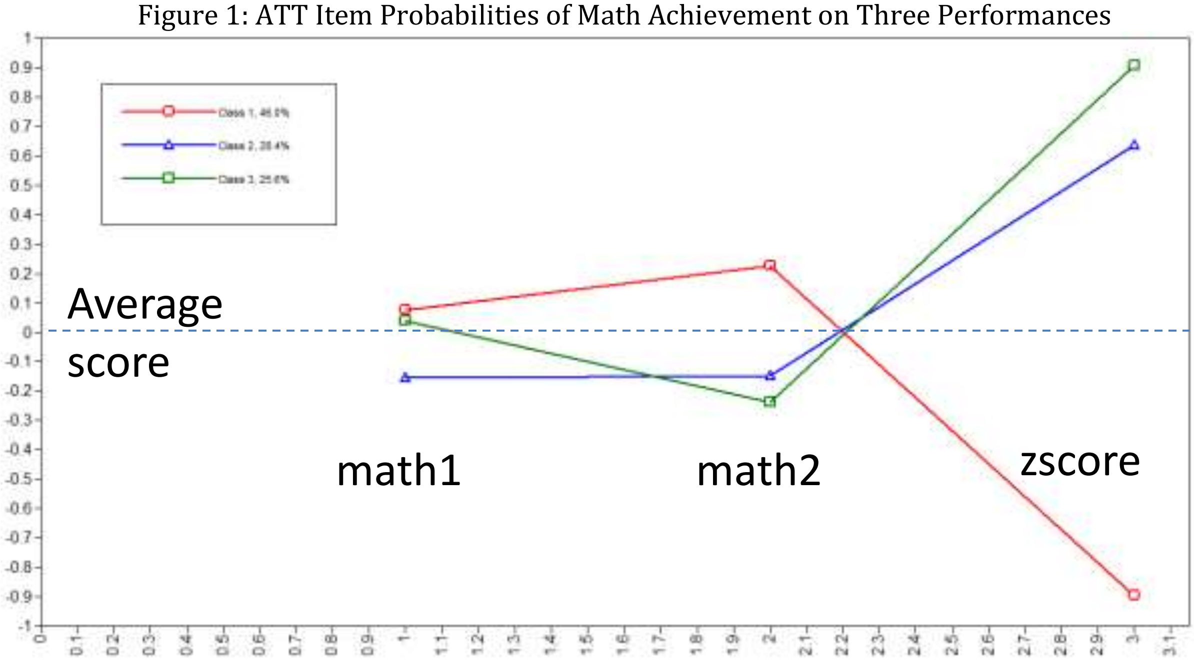
Load factor values more than 0.3 are selected for the next level statistical test (Yates, 1987). Item combination formed through load value are considered as factors and interpreted as follows:

a) Students' attitude towards GC application has 15 items with load value between 0.744 and 0.917.
b) Belief towards math has 11 items with load value between 0.300 and 0.549.
c) Motivational effort has 11 items with load value between 0.316 and 0.732.
d) Mathematics self-efficacy has 14 items with load value between 0.370 and 0.642.

The source for the above analysis is taken from a study performed by Martin et al. (2003), Koutsoulis & Cambell (2001) and Papanastasiou (2002). By results, 51 items were generated using the Geomin rotation from whole ATM and ATT variable with accurate factor loading value for second stage analysis i.e. latent class analysis (LCA). Then, at the second stage, LCA is divided into two models namely LCA for ATT (Stage 2a) and LCA for ATM (Stage 2b). Both models shall be combined into one structural equation model – SEM (Stage 3).

Stage 2a): Three Models of Latent Class (LC) for Attitude towards Technology (ATT)
In this stage, 15 items from the variable of attitude towards GC application are used to estimate the latent class model value. Based on the significant value ($p = 0.0008$) against the Log-likelihood ratio chi-square (LL), therein exists a difference between classes to allow the formation of the 3 latent classes. Besides that, the consistency of likelihood ratio via the Lo-Mendell-Rubin Likelihood Ratio Test (LMRLRT) approach also supports the choice of these 3 categories. Additionally, this test also enhances the minimum value for Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) besides the stable value of adjusted BIC (aBIC) to differentiate students' attitude towards GC application in math (Hagenaars and McCutcheon, 2002).

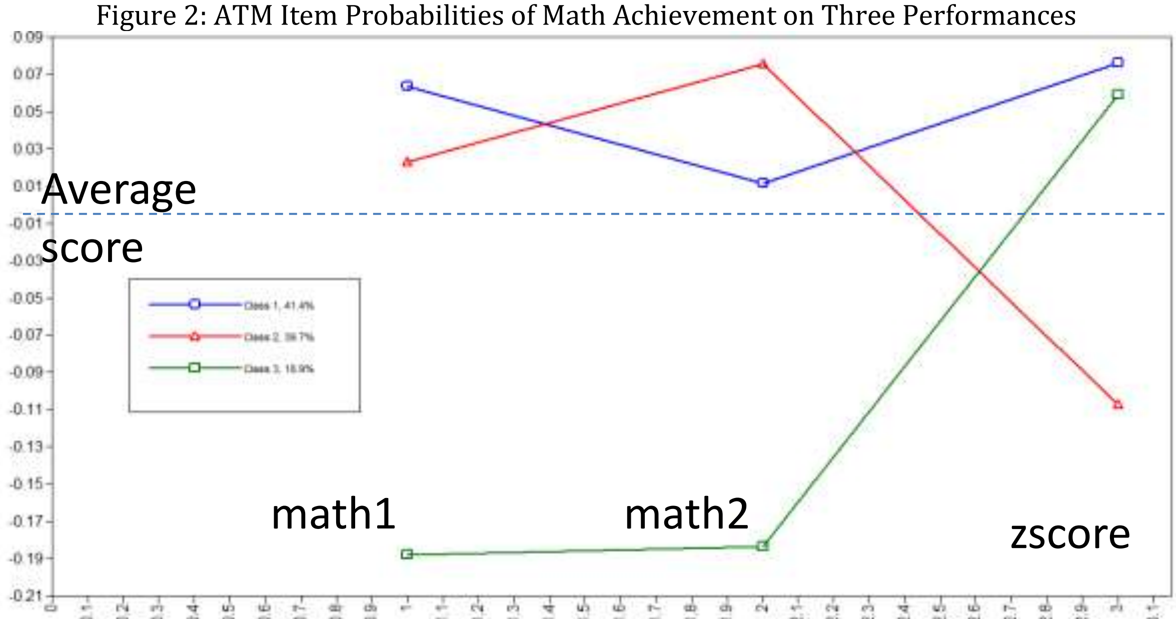
Figure 1: ATT Item Probabilities of Math Achievement on Three Performances



The first class formed from the generation of 3 latent classes is categorized as having a positive attitude towards GC application in math. Most statements were given by 369 (48.3%) students from this category were encouraging and totally agree with ever statement, to the extent that none even one gave a negative statement (disagree). The second class represented by 260 (34.1%) students is placed under ambivalent group due to their inconsistent attitude towards the capability of GC application in math. The remaining 134 (17.6%) students state their stand as uncertain and they are categorized as mainstream attitude and as the third class (Bruin, 2012). These can be expressed in Figure 1 describing students' math achievement according to the resulting latent class.

Stage 2b): Three Models of Latent Class (LC) for Atittude towards Mathematics (ATM)
Contrary to the ATT variable, ATM variable showcases three main components in the latent variable namely, belief, effort and self-efficacy. Supplied with 36 items remaining from the last elimination process (stage 1) the three models of the latent class are formed based on the significant p = 0.0.0180 to prove the existence of differences among classes. This result is supported with LL, LMRLRT value that is consistent with high entropy value (0.977). With no account for latest technology element in mathematics education, the classification of attitude towards math is concluded as class 1 – consistent attitude, class 2 – traditional attitude and class 3 – prepared attitude to improvise. This can be proven via LCA test where it is simplified in Figure 2. The difference between math achievement before and after the test is shown as students' actual attitude towards math based on the formation of latent class. Next, in terms of classification of attitude towards mathematics, the earlier weaker student group (class 3) have put the effort in improving their performance so much so that they surpassed the performance of the student group of class 2 and this is after the introduction of GC. Figure 2 also, shows encouraging achievement improvement for class 3 although having priorly poor achievement. Unfortunately, the contrary happened to the student group in class 2, where SMAWGA performance was not good and disappointing.

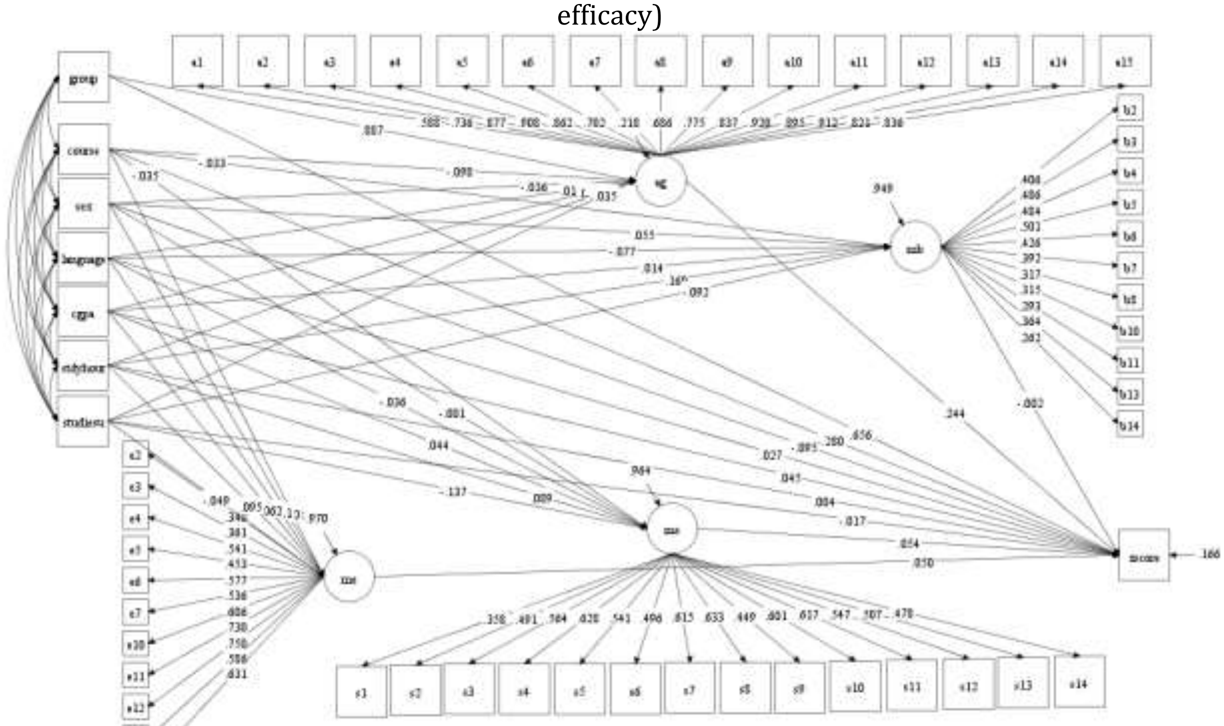
Figure 2: ATM Item Probabilities of Math Achievement on Three Performances



Level 3: Structural Equation Modelling (SEM)
For the measurement of variable intercorrelation, a total SEM test should be considered. This is seen via test in Figure 3 where shows fit indexes occurring in the model. With a significant χ^2 = *45378.562 value (p = 0.000) proves that the fitting probability model for this population is a good fit. With the Comparative Fit Index, CFI = 0.189 and Tucker Lewis Index, TLI = 0.061, it sufficiently supports that the SEM fits well enough.* Additionally, the Root Mean Square of Error Approximation

(RMSEA) is also a determining indicator for a good fit model. Even without the consideration of sample count, this model is measured as the best estimation with significant values of RMSEA = 0.089 and p = 0.000. With RMSEA value less than 0.10, this model is seen as best in proving the close and strong intercorrelation among variables. Based on the SEM results, the intercorrelation of variable SMAWGA consequented by attitude towards GC (0.244) is the strongest compared to mathematical belief (-0.03), effort (0.05) and self-efficacy (0.054) which have weak intercorrelation. This strong intercorrelation that is seen as strong is also influenced by technology exposure conducted before attitude evaluation. This is proven through a causal relationship at 0.887 between technology exposure (TE) and attitude towards GC. Furthermore, strong, significant and direct intercorrelation is also proven between TE and SMAWGA that is at 0.656. This proves that students exposed to technology, specifically GC will obtain encouraging results in math tests and would for once dodge the assumption that technology in math education is a burden to students.

Figure 3: The Standardized Regression Coefficients for the Relationship between SB (student's background), group (technology exposure) and GC (Math Score with GC Aided) as Mediated by AG (Attitude towards GC), MB (Mathematical Belief), ME (Motivational Effort) and MS (Math Self-efficacy)



For obtaining a fitting comparison model via SEM amongst groups in the technology exposure (TE) variable, the integrated model technique is used to test the invariant covariance matrices and structural relation (Barrett, 2007) via LCA direct effect. At the same time, the course variable displays strong and direct positive intercorrelation with students' achievement i.e. 0.280. This indicates that students in less critical courses are capable of outstanding achievements in mathematics when assisted with GC application.

Discussion and Conclusion

In the presentation of testing done by Quaglia & Cobbs (1996), the number of factors affecting student's performance is referred. This is because students' attitude towards technology and mathematics are two different components. Students tend to obtain encouraging results if they have several positive attitudes within them. This is proven with the strong intercorrelation between TE and SMAWGA whether directly or mediatorly (attitude towards GC). Also, through this technology exposure, students exposed to GC application tend to gain outstanding results in math test SMAWGA regardless of their past performances. This is proven with the dramatic achievement of science students in the less critical courses. As it is, science students in the critical courses have been known to have consistent achievements in all subjects including mathematics. Nevertheless, despite the inclusion of technology such as GC in math education, it is not a hindrance at all for them to maintain such tremendous achievement. With advanced technological learning aid such as the GC, it can help students of less critical courses in improving their performance in mathematics education. Most importantly is that it can change one's attitude and perception towards mathematics and technology where these were considered as difficult and gaining excellent results was impossible. Therefore, for groups categorized earlier as anti for technology in math, they were able to change their perception that not all technology has negative effects. It depends on the condition, time and students' attitude in handling the advanced technological learning aid. It is hoped that in the future, researches in mathematics education will be more focused on the method and ways to maintain students' positive attitude towards mathematics so that excellent achievement can carry on up to graduation.

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