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Personal Epistemology And Mathematics Performance

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Abstract:
Historical Data Reflected A High Failure Rate Among Students Who Undertook First-Year Mathematics Courses At One National University In Guyana. This Research Investigated The Relationship Between Epistemological Beliefs About Mathematics And Mathematics Performance Of First-Year Students At This University. A Convenience Sample Of 149 Students Who Completed A First-Year Calculus Course Responded To An Adaptation Of Wheeler's 2007 Epistemological Beliefs Survey For Mathematics (EBSM). This Instrument Measured Four Belief Dimensions: Source Of Mathematics Knowledge, Structure And Stability Of Mathematics Knowledge, Speed And Control Of Mathematics Learning, And Usefulness Of Mathematics. The EBSM Used A Likert Scale With A 1-4 Range, Where Lower Overall Scores Indicated Beliefs That Are Disadvantageous To Learning Mathematics While Higher Overall Scores Indicated Beliefs That Are Advantageous To Learning Mathematics. The Performance Measures Were Coursework, Examination, And Overall Final Scores For An Introductory Calculus Course. The Results Indicated That Overall, Students Scored Approximately 2.3 For Their Beliefs About Source Of Mathematics Knowledge, And Approximately 2.8 For The Other Belief Dimensions. Beliefs About The Source Of Mathematics Knowledge And Speed And Control Of Mathematics Learning Were Good Predictors Of Mathematics Performance, While Beliefs About Structure And Stability Of Mathematics Knowledge And Usefulness Of Mathematics Were Not. The Study Recommended The Need For Continued Assessment Of Students' Epistemological Beliefs, And Tailoring Instruction And Assessment That Would Foster Growth Of Students' Personal Epistemology That Would In Turn Improve Their Mathematics Performance.

***Key Words**: Personal Epistemology, Epistemological Beliefs, Mathematics Performance*

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I. Introduction

There is a growing concern among researchers and educators with students' lack of comprehension of mathematics. However, in the past three decades the notion of epistemological beliefs about mathematics and the role these beliefs may have on the teaching and learning of mathematics have attracted much attention from several researchers worldwide (Muis, 2004). A number of studies have investigated students' epistemological beliefs about mathematics (e.g. Schoenfeld, 1989; Schommer-Aikins, Duell & Hutter, 2005; Xiao,Yu & Yan, 2009). Epistemology is a branch of philosophy concerned with the nature of knowledge and justification of belief. Personal epistemological beliefs are defined as beliefs individuals hold about the nature and acquisition of knowledge. Researchers in this field have asserted that epistemological beliefs have an influence on how people think and reason, as well as on their motivational processes (Muis, 2004).

At the university where this study was based, students in the first year of a bachelor's degree in the sciences are required to study some mathematics. Over the last 5 years (from 2012/2013 to 2016/2017 academic years), a large proportion of the first-year students experienced difficulty with mathematics comprehension. Between 30-60 % of students obtained either grades F or D for courses such as Algebra, Basic Statistics or Calculus (students with an F grade have to repeat the course, while a D grade has a negative effect on GPA. At this university, a GPA of 2.0 is required for graduation and scoring a D in a course earns a student 1 point; this fact results in the lowering of a student's GPA when that student's GPA is calculated). In order to improve teaching/learning of mathematics at the first-year level of university, there was a need to understand the reason/s for the trend of performance.

The researcher, who has been a mathematics lecturer for over ten years at the university level has observed that students in the first year exhibit a tendency to be heavily dependent on direct instruction in mathematics courses. The researcher also noticed in students an aversion for problem-based and project-based learning activities in mathematics that involved much time and effort. A common complaint from students is that they do not see the relevance of mathematics to real life and their intended career. The researcher in his research found that those tendencies of students could be connected to their epistemological beliefs. The literature on the subject seems to indicate that a student's epistemological beliefs could have a profound effect on his/her cognitive processes and therefore affect the learning process and performance (Muis, 2004). The researcher, therefore decided to examine the beliefs about mathematics of a sample of first-year university students and how these are related to their mathematics performance. The main research question was: To what extent do students' epistemological beliefs about mathematics predict their mathematics performance? The researcher, used a survey instrument that was based on the work of Schommer (1990) and Walker Wheeler (2007) on personal epistemology to measure students' epistemological beliefs.

Schommer proposed that epistemological beliefs may be conceived as a multidimensional construct. Schommer posited that the one-dimensional description of epistemology, embedded in the developmental paradigm proposed by William Perry in 1970, could not capture and account properly for the complex nature of personal epistemology. Thus, the epistemological beliefs paradigm adopts a multidimensional view and has primarily sought to identify the underlying dimensions of an individual's beliefs scheme about knowledge and knowing. In this paradigm Schommer describes personal epistemology as a 'system of more or less independent beliefs.' By 'system' she meant that there was more than one dimension to consider. By 'more or less independent' she implies a fluid theory, whereby the belief dimensions do not necessarily develop simultaneously. A person could have naïve beliefs in one dimension coexisting with sophisticated beliefs in another dimension (Schommer, 1990). Naïve beliefs are disadvantageous to learning mathematics while sophisticated beliefs are advantageous to learning mathematics (Muis, 2004).

Schommer hypothesized five different sub-constructs or dimensions of epistemological beliefs, namely: 'beliefs about the structure of knowledge' (ranging from isolated bits to integrated concepts); 'beliefs about the stability of knowledge' (ranging from certain to evolving); 'beliefs about the source of knowledge' (ranging from handed down by authority to derived from reason and evidence); 'beliefs about the speed of learning' (from quick or not at all to gradual); and 'beliefs about control of learning' (ranging from fixed at birth to improvable). Schommer found empirical support for the existence of four of the proposed beliefs dimensions she hypothesized. These dimensions were 'beliefs about the structure of knowledge,' 'beliefs about the stability of knowledge,' 'beliefs about the control of learning' and 'beliefs about the speed of learning' (Schommer, 1993a, 1993b; Schommer, Crouse, & Rhodes, 1992; Schommer & Walker, 1995; Schommer, Calvert, Gariglietti, & Bajaj, 1997). While Schommer did not find support for the existence of the dimension 'beliefs about source of knowledge' in her work, studies in Asia supported the existence of this dimension (e.g. Lin, 2002; Chan & Elliot, 2002).

The researcher chose to underpin his investigation using Schommer's paradigm because the epistemological beliefs system paradigm has gained hold in personal epistemology research around the world. Also, a few studies that are based on Schommer's paradigm have been conducted to investigate students' epistemological beliefs specific to the domain of mathematics (e.g. Buehl & Alexander, 2005 (USA), Mason, 2003 (Europe), Xiao, Yu & Yan, 2009 (Asia). In these studies, there are several survey tools developed to investigate the epistemological beliefs of students about mathematics specifically (Schoenfeld, 1989; Schommer-Aikins, Duell & Hutter, 2005; Wheeler, 2007). These surveys were tested by factor analysis of students' responses, and were found to empirically support the existence of the belief dimensions that Schommer (1990) identified. Denna Walker Wheeler (2007) developed a comprehensive epistemological survey instrument specific to mathematics in her doctoral dissertation.

The researcher, in order to situate the present study, analyzed nine studies that investigated students' domain-specific epistemological beliefs about mathematics and the relationships between these beliefs and students' performance in mathematics. All of the studies included one or more of the epistemological belief dimensions proposed by Schommer (1990). The researcher analyzed the instrument, methodology, statistical analyses and the findings of each study. This review presents justification for conducting the present research. The findings of several studies suggest that the nature of students' personal epistemological beliefs about mathematics could be predictive of their performance in mathematics.

Beliefs About Source of Mathematics Knowledge

The researcher examined two studies to justify the inclusion of the independent variable 'beliefs about source of mathematics knowledge' in the present investigation. Much of Schommer's work did not include the belief dimension 'source of knowledge.' However, from 1990 onward researchers have sought to ascertain domain-specific epistemological beliefs of individuals. Among the belief dimensions was 'epistemological beliefs about the source of mathematics knowledge'. Epistemological beliefs about the source of mathematics knowledge refers to beliefs individuals hold about how knowledge/truths in mathematics are arrived at; whether they are arrived at by reasoning and logic or handed down by authority (Muis, 2004).

There are only a few studies that investigated students' epistemological beliefs regarding source of mathematics knowledge and even fewer that have related them to students' performance. Two of such studies that did both were reviewed (Szydlik, 2000; Buehl & Alexander, 2005). Despite Schommer's difficulty with extracting the belief dimension, source of knowledge, the foregoing studies considered, do provide support for the existence of the domain-specific belief dimension 'source of mathematics knowledge', and that there is a relationship between this belief dimension and mathematics performance. However, the few studies that were done are not enough to establish a trend of existence/nonexistence of this belief dimension among population of students varying in culture, educational systems and environments.

The present research presents findings regarding beliefs about source of knowledge in an educational system that is typical of an English speaking Caribbean country. As regards the cultural background of the population; the present study presents findings that was conducted among a population that is mostly influenced by Indo-Guyanese and Afro-Guyanese cultures.

The studies by Szydlik (2000) and Buehl and Alexander (2005) were also able to establish a positive relationship between the belief dimension, 'source of mathematics knowledge' and performance. However, there are not enough studies to indicate a trend of causation. The current study added to the literature regarding the extraction of the belief dimension, 'source of mathematics knowledge' and its connection to mathematics performance.

Beliefs About Stability and Structure of Mathematics Knowledge

In the domain of mathematics, beliefs about the 'stability of mathematics knowledge' could range from the view that mathematics knowledge is absolutely certain/unchanging ('naïve' beliefs) to the view that mathematics is constantly changing/evolving/expanding ('sophisticated' beliefs). While 'beliefs about the structure of knowledge' range from isolated bits (naive beliefs) to integrated concepts (sophisticated beliefs). The researcher, examined five studies that related beliefs about 'structure of mathematics knowledge' and 'stability of mathematics knowledge' to mathematics performance: Mason (2003), Steiner (2007), Xiao, Yu and Yan (2009), Koller (2001), Buehl and Alexander (2005). Of the five studies reviewed, three were at the high school level and two at university level. They also were done in different parts of the world. The two university level studies were from the US; the high school studies were from China, Italy and Germany.

All the studies considered used questionnaire data to investigate beliefs of students. The methods used to establish patterns and relationships were varied. The Italian and Chinese studies used post-hoc Tukey's Honestly Difference for analyses of means and regression, while the German study used path analyses. One university study used correlation and regression analyses, while the other used ANOVA, MANOVA and cluster analyses. Xiao et al. (2009) concluded that epistemological beliefs were not good at predicting performance and pointed to limitations of regression analyses. Mason and Steiner, on the other hand, were able to use correlation and regression to establish relationships, while Koller and Buehl used other methods that helped to detect indirect relationships. Overall, the varied methods of analyses used in the studies examined did not seem to limit the detection of relationships between the belief dimension and performance as Xiao et al. claimed. The present research, used correlation and regression analyses. The researcher would like to refer to the claims by Xiao et al. (2009). Xiao et al. (2009) claimed that their findings were different from Western research results, in that epistemological beliefs could not predict mathematics achievement very well and that the social-cultural differences could account for the inconsistency (the latter claim was made without elaboration). Even though the present researcher only considered a few studies, these studies were from different cultural settings – US, Italy. China and Germany. All the studies showed consistent results for the belief dimension, structure of mathematics knowledge, and its relationship with mathematics performance. Belief about structure of mathematics knowledge was extracted in all studies and its relationship with performance was found in all these studies.

However, in the studies considered, relationships were not consistently found between the belief dimension, stability of mathematics knowledge and performance. Of the two studies that investigated the belief dimension, stability of mathematics knowledge and mathematics performance, the Chinese study claimed no relationship exists. The researcher does not think that there are enough studies investigating stability of mathematics knowledge and mathematics performance to corroborate the claims of Xiao et al. Hofer and Pintrich (1997) cited this paucity of studies that examined cross-cultural differences. Therefore a study done in the Caribbean with a different culture and educational system from the ones considered could serve to find out whether cultural differences made a difference to epistemological beliefs.

These five studies serve as the rationale for including the belief dimensions 'structure of mathematics knowledge' and 'stability of mathematics knowledge.' However, due to some preliminary work involving piloting of a questionnaire with these two scales and examining their reliability has led the researcher to merge these two related dimensions into one so as to improve reliability of the instrument. Therefore, 'Beliefs about the Structure and Stability of Mathematics Knowledge' are beliefs of students regarding whether mathematics is made up of isolated bits of facts that are fixed/unchanging, or whether mathematics is made up of integrated concepts that are constantly evolving (Schommer, 1990).

Beliefs About Speed and Control of Mathematics Learning

'Beliefs about the speed of mathematics learning' range from beliefs that mathematics learning should be quick or not at all (naive) to gradual, takes time (sophisticated); and 'beliefs about control of learning' ranging from fixed at birth (naive) to improvable through hard work/effort (sophisticated). The researcher examined four studies that related 'speed of mathematics learning' and 'control of mathematics learning' to mathematics performance. In the two studies by Schommer-Aikins et al. (2005, 2013) path analyses uncovered indirect relationships between epistemological beliefs about speed and control of mathematics learning and performance. In the Mason (2003) study, regression analyses were only able to uncover a relationship between speed of mathematics learning and mathematics performance, but no relationship between control of mathematics learning and mathematics performance. Xiao et al (2009) found no relationship between control of mathematics learning and performance. These studies indicate inconsistent results and further studies are needed to establish any pattern. The studies considered did not elaborate on the reasons for the relationships/non-relationships between beliefs about the speed and control of mathematics learning and performance. The present research sought to furnish possible explanations for the relationship/non-relationship between speed and control and performance.

Xiao et al.'s allusion to cultural differences affecting the relationships is another reason for further investigation. In the Chinese culture much value is placed on diligence, working hard, and effort. Effort is seen to be very important for vertical mobility and acquired status in traditional Chinese societies (Chan & Elliot, 2002). Yet Xiao et al. found no relationship between effort to learn mathematics and performance. The present study which investigated students' beliefs about speed and control of mathematics learning, and which is set in a Caribbean country with a more lax work ethic than Chinese society, added to the limited studies available for reference. Again, due to some preliminary work involving piloting of a questionnaire with these two scales and examining their reliability has led the researcher to merge these two related dimensions into one so as to improve reliability of the instrument.

Discussion of Beliefs about Usefulness of Mathematics

Mason (2003) and Schommer (2005) conceptualized the domain-specific epistemological belief dimension 'Useful Mathematics.' This dimension deals with learners' belief that mathematics is useful in other subject areas and life in general. Agreeing with this position is associated with sophisticated beliefs while disagreeing is associated with naïve beliefs.

Mason's (2003) study found that the belief that 'mathematics is useful for everyday life' was a leading predictor of students' mathematics performance. The study by Schommer-Aikins, Duell, and Hutter (2005) the analysis showed a connection between 'useful mathematics' and performance in mathematics problem-solving. They found that the more students believed in useful math, the better they were at problem-solving. Schommer-Aikins and Duell (2013) also used a 'Mathematics Is Useful' Scale. They found that the domain-specific mathematical problem-solving belief 'mathematics takes time and is useful' had direct effects on cognitive depth and mathematical problem solving. From these studies, a predictive relationship between belief in the usefulness of mathematics and performance is emerging; but more studies are needed to establish this trend.

Summary of Review

The researcher found that in the nine studies reviewed, there is evidence of the existence of a number of sub-constructs or dimensions of students' domain-specific epistemological beliefs about mathematics. The researcher also found that students' epistemological beliefs about mathematics have been fairly consistent in predicting performance in mathematics. The domain-specific epistemological belief dimensions that have emerged to be predictive factors of students performance are: (1) 'Source of Mathematics Knowledge,' (2) 'Structure of Mathematics Knowledge,' (3) 'Speed of Mathematics Learning,' (4) 'Control of Mathematics Learning,' and (5) 'Usefulness of Mathematics.' Fairly consistently, students with beliefs that are at the 'sophisticated' end of the continuum of these belief dimensions perform better than students with beliefs that are at the 'naïve' end. However, domain-specific epistemological belief about 'Stability of Mathematics Knowledge,' has been the least investigated and the limited studies done have shown that this belief dimension did not consistently predict performance.

Most of the studies in this review were quantitative in nature and used questionnaires with likert-type scales to measure the belief dimension/s of interest. The statistical analyses used in most of the studies involved correlation and regression and path analyses to ascertain relationships. The researcher working in line with these findings, also designed a quantitative study that involved the use of a questionnaire that employed a likert-type scale to measure the epistemological belief dimensions of students. Similar to the analyses in the studies in this review, the researcher used ANOVA, correlation and regression analyses to analyse the data collected. The actual mathematics performance of students was measured by final exam scores/grades in a number of the studies examined. The researcher followed this same pattern, and used the final score/grade of a mathematics course as the measure of students' actual mathematics performance.

II. Material And Methods

Design

The researcher in this study used a cross-sectional survey design. The researcher's aim in this study was to relate quantitatively the beliefs about mathematics knowledge of a sample of students at a particular time to mathematics performance measures of the same sample of students.

Subjects & selection method

The target population in this research was the first-year Natural Sciences students from a national university in Guyana that were registered for the 2017/2018 academic year. The accessible population was the group of students registered for an Introductory Calculus course that was taken by all majors. The researcher took a convenient sample of 162 students. There were 52 males and 111 females. Their age ranged from 17-40 years.

Procedure/Methodology

The data collection tool in this research was a questionnaire. The survey was designed to measure all the independent variables. The researcher chose to make extensive use of the instrument developed by Denna Walker Wheeler (2007), to measure the various sub-constructs of students' epistemological belief posited by Schommer (1990). Walker Wheeler (2007) developed an epistemological beliefs survey for mathematics (EBSM) using college students in the United States of America. The reliability of that instrument was tested and gave a reliability coefficient of $\alpha = 0.93$. Construct Validity of the EBSM was verified by relating it to instruments that were used in several previous studies The researcher made modifications to the instrument that Walker Wheeler developed. These modifications were based on material in the literature on students' epistemological beliefs about mathematics, as well as the opinions/views of first-year university students regarding the wording of statements in the EBSM. Another modification that was made to the Walker Wheeler (2007) instrument was that a four-point likert-type scale replaced the five point type. The scale was: Strongly Agree, Agree, Disagree, Strongly Disagree. The rationale behind this change from five-point to four-point likert-type scale was to avoid respondents taking a neutral position on statements in the survey. A pilot survey was conducted with this instrument among first-year Natural Sciences students in early April 2018. Responses were forward-coded with Strongly Agree = 1, Agree = 2, Disagree = 3 and Strongly Disagree = 4. For reverse-coded items Strongly Agree = 4, Agree = 3, Disagree = 2 and Strongly Disagree = 1. Reverse-coded items are marked with an asterisk (*) in the survey instrument. The researcher calculated reliability coefficients for each scale in the survey instrument using the pilot data obtained. The researcher decided to merge related scales due to low reliability for certain scales of the survey instrument. The precedent of merging related scales was seen in Schommer et al. (2005). The merged scales improved reliability. The resulting scales were: (1) Beliefs about Source of Mathematics Knowledge, (2) Beliefs about Structure and Stability of Mathematics Knowledge (merged scale), (3) Beliefs about Speed and Control of Mathematics Learning (merged scale) and (4) Usefulness of Mathematics. The final questionnaire is shown below as Table 1.

Table 1: Survey Instrument

Students' Survey

USI .... Gender: .... Major: ....Age: ....

Direction: Place an x in the box of your choice for each statement

	Item	Response			
	Beliefs About Source of Mathematical Knowledge	Strongly Agree	Agree	Disagree	Strongly Disagree
1	Learning mathematics depends mostly on having a good teacher.				
2	I learn mathematics best when watching the teacher work examples of problems.				
3	The quality of a mathematics class is determined mostly by the teacher.				
4	Sometimes I accept answers from my mathematics teacher even if I do not understand them.				
5	Mathematics is something I cannot learn on my own.				
6	To solve mathematics problems you have to be taught the right procedure.				
7*	In mathematics I prefer to be creative and discover my own methods of solutions.				
8*	I learn mathematics best by working practice problems.				
	Beliefs About Structure and Stability of Mathematical Knowledge	Strongly Agree	Agree	Disagree	Strongly Disagree
9	Most of what is true in mathematics is already known.				
10	New ideas have no place in a mathematics class.				
11	Mathematics is unchanging.				
12*	Answers to questions in mathematics change as mathematicians gather more information.				
13	Mathematics is really just knowing the right formula for the problem.				
14*	I prefer a mathematics teacher who shows students lots of different ways to look at the same problem.				
15	There is usually one best way to solve a mathematics problem.				
16	In mathematics, the answers are always either right or wrong.				
17*	It is more important to know why a formula works rather than memorizing it.				
18*	In mathematics class, I can understand the material better if I relate it to the real world.				
19	When solving mathematics problems, the key is knowing the best method for each type of problem.				
20	Mathematics is mostly facts and procedures that have to be memorized.				
21*	I like to find different ways to work mathematics problems.				
22	I find it confusing when the teacher shows more than one way to work a mathematics problem.				
23	I do not care about why a mathematical procedure works, just show me how to work the problem.				
24*	Understanding how mathematics is used in other subjects helps me to comprehend the concepts.				

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24*	Understanding how mathematics is used in other subjects helps me to comprehend the concepts.				

	Beliefs About Speed and Control of Mathematical Learning	Strongly Agree	Agree	Disagree	Strongly Disagree
25*	It takes a lot of time to learn mathematics.				
26	I should be able to solve mathematics problems quickly.				
27*	When I encounter a difficult mathematics problem, I stick with it until I solve it.				
28*	Given enough time, almost everyone could learn Calculus if they really tried.				
29	If I do not understand something presented in mathematics class, going back over it later will not help.				
30	If I can't solve a mathematics problem in a few minutes I am not going to solve it without help.				
31	I should not have to spend more than a few minutes to complete a mathematics homework problem.				
32	It is frustrating to read a mathematics problem and not know immediately how to begin to solve it.				
33*	When I am having trouble in mathematics class, better study habits can make a big difference.				
34*	I am confident I could learn Calculus if I put in enough effort.				
35*	Learning good study skills can improve my mathematics ability.				
36	Even if I work hard I will never really understand mathematics.				
37	I knew at an early age what my mathematics ability was.				
38	It is frustrating when I have to work hard to understand a mathematics problem.				
39	I cannot change the mathematics ability I was born with.				
40	Some people are born with great mathematics ability and some are not.				
	Beliefs About Real World Applicability of Mathematics	Strongly Agree	Agree	Disagree	Strongly Disagree
41	Understanding mathematics is important for mathematicians, economists, and scientists but not for most people.				
42	The only reason I do mathematics is because every student has to.				
43*	I need to learn mathematics for my future work.				
44*	I can apply what I learn in mathematics to other subjects.				
45*	It is easy to see the connections between the mathematics I learn in class and real world applications.				
46	I am rarely able to use the mathematics I have learned in other subjects.				
47*	Mathematics provides the foundation for most of the principles used in. science and business.				
48*	Mathematics helps us better understand the world we live in.				

Reliability of Survey Instrument

The researcher used the pilot data obtained and SPSS to calculate the reliability coefficient of each scale in the survey. The results of the reliability tests revealed that the instrument needed refinement. Related scales were merged and minor changes to wording were made. The scales in the final survey instrument are: (1) Beliefs about Source of Mathematics Knowledge, (2) Beliefs about Structure and Stability of Mathematics Knowledge (merged scale), (3) Beliefs about Speed and Control of Mathematics Learning (merged scale), (4) Usefulness of Mathematics (5) Perceived Mathematics Capability.

The reliability coefficients of the final scales range from 0.578 to 0.807 (overall α =0.709). The researcher also calculated the reliability of the instrument using the data collected from the actual study. Table 2 summarizes the reliability coefficients of the various scales in the survey that were calculated from the pilot and actual data obtained.

Table 2: Reliability of Survey Instrument

Scale	Reliability Coefficient (α)	
	Pilot	Actual
Beliefs about Source of Mathematics Knowledge	0.606	0.644
Beliefs about Structure and Stability of Mathematics Knowledge	0.578	0.719
Beliefs about Speed and Control of Mathematics Learning	0.729	0.716
Beliefs about Usefulness of Mathematics	0.807	0.758
Overall	0.680	0.709

The researcher proceeded with the survey despite the reliability coefficient for the scale, 'Beliefs about Source of Mathematics Knowledge' was found to be below the acceptable 0.7 for a psychological construct

(Kline, 1999). The researcher proceeded with the presumption that the reliability could increase with a larger sample size (Yurdugül, 2008). However, the reliability still did not reach/exceed 0.7 in the actual survey. The researcher found that even though the scale's reliability was questionable; it was found to be a leading predictor of the dependent variables and therefore included it in his discussion. Therefore, the findings connected with the scale, 'Beliefs about Source of Mathematics Knowledge' should be interpreted with caution.

Validity of Survey Instrument

The scales measuring students' epistemological beliefs about mathematics in the survey were similar to scales in Walker Wheeler's (2007) Epistemological Beliefs Survey for Mathematics (EBSM). The researcher's argument is that if the scales in the EBSM were found to have construct validity then the scales in the survey that were similar to the EBSM would also have construct validity. Walker Wheeler explored the face validity (an indicator of construct validity) of the EBSM through the analysis of relationships with demographic variables including age, gender, academic classification, student's mathematical experience and endorsement of mathematics related attitude statements. Walker Wheeler also explored the convergent validity (another indicator of construct validity) of the EBSM through the analysis of relationships with other constructs including scores on the Epistemic Beliefs Inventory (EBI), the Achievement Goal Inventory (AGI) and the Implicit Theories of Intelligence Scale (TIS). First she compared the EBSM to the Epistemic Beliefs Inventory (EBI) developed by Shraw, Bendixen and Dunkle in 2002. Walker Wheeler claimed that the EBI was the most psychometrically sound measure of general epistemological beliefs currently available. She also compared the EBSM to the Achievement Goal Inventory (AGI) developed by Grant and Dweck in 2003, which in her opinion took into consideration the most recent refinements in Achievement Goal Theory research. Finally, Walker Wheeler compared the EBSM to The Implicit Theories of Intelligence Scale (TIS) developed by Dweck in 2000, which in her opinion was a reliable and valid measure of one's implicit theory of intelligence.

The researcher also explored the face and content validity of the survey instrument. The researcher sought the opinions of students regarding the statements in the survey and made slight modifications to the wording of some statements based on the feedback from students. Content validity was also checked by comparing the various scales with similar scales used in studies such as Schommer et al. (2005), Buehl and Alexander (2005) and Schoenfeld (1989).

Procedure for Data Collection

The researcher also sought permission from the university to allow the researcher to conduct the pilot and final surveys. The researcher enlisted the help of the lecturer/s of the faculty that were teaching the Calculus course in the first year to assist in the execution of the pilot and final surveys. Finally, the researcher obtained final exam scores/grades for the students in the sample from the Office of the Registrar. The student data obtained were coded so that the confidentiality and anonymity of the participants were preserved.

Procedure for Data analysis

The researcher coded the demographic information and responses in the survey. The numerical data of the survey were then entered into SPSS 20 and this version of the programme was used to do all subsequent calculations and analyses. The problem of missing values was addressed by using the valid item means to fill in the missing responses. The mean scores of the independent and dependent variables were also computed.

The researcher, in order to obtain an overview of the data, calculated descriptive statistics such as means and standard deviations for all the variables. Histograms of all variables were generated. The researcher used One Way ANOVA analysis to check for differences in each independent variable and one dependent variable, according to gender, age, and major. Correlation among variables was calculated to detect any multicollinearity. Finally, regression analysis was used to answer the research questions regarding the relationships between students' epistemological beliefs and their mathematics performance.

Statistical analysis

The researcher coded the demographic information and responses in the survey. The numerical data of the survey were then entered into SPSS 20 and this version of the programme was used to do all subsequent calculations and analyses. The problem of missing values was addressed by using the valid item means to fill in the missing responses. The mean scores of the independent and dependent variables were also computed.

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III. Result

The researcher analyzed and presented the structure of the various beliefs of the students in the sample using descriptive statistical measures. One way Analysis of Variance examined the difference in the levels of the means of the independent variables. Correlations described the linear relationship between each of the independent variables and the dependent variables. The researcher then used regression analysis to investigate the relationships between the various epistemological beliefs of students and their mathematics performance.

The accessible population consisted of the 218 first-year Natural Sciences students from the who did the introductory course, Calculus in the academic year 2017/2018. The survey was distributed to the 218 students, but only 162 filled out and returned the survey. However, of the 162 questionnaires that were returned only 149 (68% of the accessible population) had sufficient information to be tabulated. Of the total number of 9834 possible responses in Section B of the survey, there were 211 (0.02%) missing values. The researcher used the mean of a particular item to fill in these missing values so that data for analysis would not be lost.

Table 3: Descriptive Statistics of Variables

	Variable Type	N	Mean	Std. Deviation
Source_Average	Ind.	149	2.23	.377
StructureStability_Average	Ind.	149	2.88	.302
SpeedControl_Average	Ind.	149	2.87	.307
Usefulness_Average	Ind.	149	2.86	.496
PerfCW	Dep.	149	24.76	7.770
PerfEXam	Dep.	149	29.80	14.193
PerfOverall	Dep.	149	54.41	21.398
Valid N (listwise)		149		

Table 3 shows that the means of all of the independent variables (beliefs about structure and stability of mathematics knowledge, speed and control of mathematics learning and usefulness of mathematics) are approximately 2.9, except for beliefs about the source of mathematics knowledge (2.2). The standard deviations are less than 0.5 for all the independent variables, indicating that there was not much variation in the individual means of the respondents from the overall means. A value closer to 1 indicates more 'naïve' beliefs while a value closer to 4 indicates 'sophisticated' beliefs. Therefore, the values for the overall means calculated indicate that for the belief dimension 'source of mathematics knowledge' the students overall have more 'naïve' beliefs; while for the belief dimensions 'structure and stability of mathematics knowledge,' 'speed and control of mathematics learning' and 'usefulness of mathematics' the respondents overall reported beliefs that are tending to more sophisticated beliefs. Note, however, that no mean reaches 3 (agree).

The overall mean for the Coursework of the respondents is 24% out of 40% with a standard deviation of 7.7. The large value of the standard deviation which gives a coefficient of variation of approximately32% (mean/sd * 100%) indicate that there was a lot of variation in the individual coursework scores from the overall mean of the respondents (mean±sd range from 16.3% to31.7% within which approximately 68% of the scores will lie in a normal distribution). The overall mean of the respondents' scores for the exam is 29.8% out of 60%, with a standard deviation of 14. This large value of the standard deviation also indicates that the individual scores for the exams were very dispersed from the overall mean of the respondents (coefficient of variation= 49%; mean±sd range 15.8% to 43.8%). The overall mean of the respondents for their Overall Performance was 54.4 with a standard deviation of 21. This large value of the standard deviation was a consequence of the large values for the standard deviations for the Coursework and the Exam (the Overall Performance was the sum of the Coursework and Exam). This large value of the standard deviation as a consequence also meant that there were large variations in the Overall Performance of the respondents.

Comparison of Means (One Way ANOVA Tests)

The researcher used One Way ANOVA analysis to compare means for the levels of each of the independent/dependent variable using gender, major and age as sorting variables. The researcher first used One Way ANOVA to compare the means of the independent variable Source_Average with respect to gender, campus, subject major, and age. Table 4 summarizes the findings.

Table 4: Summary of Findings for Source_Average One Way ANOVA Tests

Sorting Variable	Category	Number	Mean	Standard Deviation	Homogeneity Of Variances	Significance of ANOVA
Gender	Male	49	2.2533	0.41982	Yes (sig. 0.364)	0.665
	Female	100	2.2247	0.35645		No Difference
Major	Biology	100	2.1826	0.33955	No (sig. 0.015)	0.365 (Welch)
	Chemistry	26	2.2933	0.43581		
	Computer Science	9	2.3194	0.44243		

	Mathematics	12	2.3646	0.26360		
	Physics	2	2.8750	1.06066		No Difference
Age	16-20	105	2.2200	0.36170	Yes(sig. 0.518)	0.402
	21-25	16	2.3182	0.37124		
	26-30	10	2.2564	0.33762		
	31-35	6	2.5000	0.62249		
	36 and over	3	2.3333	0.26021		No Difference

The One Way ANOVA procedure compares the means of groups within the sample. For example the One Way ANOVA procedure for Source_Average with gender as the sorting variable, compares the Source_Average mean of all male respondents with the Source_Average mean for all female respondents. The One Way ANOVA procedure revealed that there was no difference in the means for Source_Average for any of the groups within the sorting variables: gender, campus, subject major and age (significance of ANOVA - p>0.05 in all cases).

The independent variable Source_Average is the measure of respondents' beliefs regarding the 'source of mathematics knowledge.' A low mean is indicative that the group of respondents within the sorting variable is leaning towards 'naïve' belief that the teacher is the source of mathematics knowledge while a high mean is indicative that the group is leaning towards the sophisticated belief that students can create mathematics knowledge. The One Way ANOVA procedure indicates that the beliefs for all the groups within each sorting variable are all homogeneous and lean towards naïve beliefs about the source of mathematics knowledge.

The researcher next used One Way ANOVA to compare the means of the independent variable StructureStability_Average with respect to gender, campus, subject major, and age. Table 5 summarizes the findings.

Table 5 Summary of Findings for StructureStability_Average One Way ANOVA Tests

Sorting Variable	Category	Number	Mean	Standard Deviation	Homogeneity Of Variances	Significance of ANOVA
Gender	Male	49	2.8840	0.29138	Yes (Sig. 0..533)	0.866
	Female	100	2.8916	0.30855		No Difference
Major	Biology	100	2.8722	0.29310	Yes (sig. 0.198)	0.097
	Chemistry	26	2.9749	0.33824		
	Computer Science	9	2.7455	0.15584		
	Mathematics	12	2.8865	0.33202		
	Physics	2	3.2813	0.13258		No Difference
Age	16-20	105	2.8916	0.30821	Yes(sig. 0.329)	0.424
	21-25	16	2.9032	0.29574		
	26-30	10	3.0061	0.21088		
	31-35	6	3.0104	0.40968		
	36 and over	3	2.9013	0.30381		No Difference

The One Way ANOVA procedure indicates that there was no difference in the means for StructureStability_Average for the groups within the sorting variables: gender, subject major and age (significance of ANOVA - p>0.05 in all cases). The independent variable StructureStability_Average is the measure of respondents' beliefs regarding the 'structure and stability of mathematics knowledge.' A low mean is indicative that the group of respondents within the sorting variable is leaning toward the naïve belief that mathematics knowledge is made up of isolated bits of facts/concepts that are unchanging. On the other hand, a high mean is indicative that the group is leaning towards the sophisticated belief that mathematics knowledge is made up of interrelated concepts that are constantly evolving. The One Way ANOVA procedure indicates that the beliefs for all the groups within the sorting variables gender, subject major, and age are all homogeneous and lean towards sophisticated beliefs about the structure and stability of mathematics. However, the beliefs for the groups within the sorting variable, 'campus', are not homogeneous. While the groups from both campuses lean towards sophisticated beliefs regarding the structure and stability of mathematics knowledge; the group from the Tain campus has a greater leaning than the group from Turkeyen.

The researcher further used One Way ANOVA to compare the means of the independent variable, SpeedControl_Average, with respect to gender, campus, subject major, and age. Table 6 summarizes the findings.

Table 6 Summary of Findings for SpeedControl_Average One Way ANOVA Tests

Sorting Variable	Category	Number	Mean	Standard Deviation	Homogeneity Of Variances	Significance of ANOVA
Gender	Male	49	2.8870	0.31993	Yes (Sig. 0..703)	0.644
	Female	100	2.8621	0.30239		No Difference
Major	Biology	100	2.8696	0.30300	Yes (sig. 0.433)	0.867
	Chemistry	26	2.8497	0.35076		
	Computer Science	9	2.9028	0.36054		
	Mathematics	12	2.8594	0.24151		
	Physics	2	3.0938	0.13258		No Difference
Age	16-20	105	2.8741	0.30821	Yes(sig. 0.462)	0.380
	21-25	16	2.9242	0.25023		
	26-30	10	3.0074	0.32246		
	31-35	6	2.7813	0.40068		
	36 and over	3	2.9013	0.30381		No Difference

The One Way ANOVA procedure indicates that there was no difference in the means for SpeedControl_Average for the groups within the sorting variables: gender, subject major and age (significance of ANOVA - $p>0.05$ in all cases). The independent variable, SpeedControl_Average, is the measure of respondents' beliefs regarding the 'speed and control of mathematics learning.' A low mean is indicative that the group of respondents within the sorting variable is leaning toward the naïve belief that mathematics learning should be quick and that the ability to learn mathematics is only for the gifted. On the other hand, a high mean is indicative that the group is leaning towards the sophisticated belief that mathematics learning takes time and effort and anyone could learn mathematics once they put in the time and effort. The One Way ANOVA procedure indicates that the beliefs for all the groups within the sorting variables: gender, subject major, and age, are all homogeneous and lean towards sophisticated beliefs about the speed and control of mathematics learning.

The researcher finally used One Way ANOVA to compare the means of the independent variable, Usefulness_Average, with respect to gender, campus, subject major, and age. Table 7 summarizes the findings.

Table 7 Summary of Findings for Usefulness_Average One Way ANOVA Tests

Sorting Variable	Category	Number	Mean	Standard Deviation	Homogeneity Of Variances	Significance of ANOVA
Gender	Male	49	2.8390	0.55631	Yes (Sig. 0..181)	0.685
	Female	100	2.8742	0.46772		No Difference
Major	Biology	100	2.8220	0.50840	Yes (sig. 0.785)	0.147
	Chemistry	26	2.8885	0.44381		
	Computer Science	9	2.7917	0.52291		
	Mathematics	12	3.0924	0.43219		
	Physics	2	3.5000	0.35355		No Difference
Age	16-20	105	2.8508	0.48871	Yes(sig. 0.151)	0.711
	21-25	16	2.9896	0.51199		
	26-30	10	3.0017	0.41004		
	31-35	6	2.9348	0.83745		
	36 and over	3	2.7083	0.14434		No Difference

The One Way ANOVA procedure indicates that there was no difference in the means for Usefulness_Average for the groups within the sorting variables: gender, subject major and age (significance of ANOVA - $p>0.05$ in all cases). The independent variable, Usefulnes_Average, is the measure of respondents' beliefs regarding the 'usefulness of mathematics.' A low mean is indicative that the group of respondents within the sorting variable is leaning toward the naïve belief that mathematics is not useful in the study of the other sciences and in their future work. On the other hand, a high mean is indicative that the group is leaning towards the sophisticated belief that mathematics is useful in the study of the other sciences and in their future work. The One Way ANOVA procedure indicates that the beliefs for all the groups within the sorting variables

gender, subject major, and age are all homogeneous and lean towards sophisticated beliefs about the usefulness of mathematics.
In summary, The One Way ANOVA procedure revealed that there was no difference in the means for Source_Average for any of the groups within the sorting variables: gender, subject major and age.

Correlations

Table 8 is the correlation matrix for all the independent variables, Source_Average, StructureStability_Average, SpeedControl_Average and Usefulness_Average. There exist significant correlations among all of the variables. However, no correlation is greater than 0.7 (according to the general rule of thumb a correlation greater than 0.7 is considered strong and indicates multicollinearity among variables).

Table 8 Correlation Matrix of Variables

		Source_ Average	StructureStability_Average	SpeedControl_ Average	Usefulness_ Average
Source_ Average	Pearson Correlation	1			
	Sig. (2-tailed)				
	N	149			
StructureStability_ Average	Pearson Correlation	.361	1		
	Sig. (2-tailed)	.000			
	N	149	149		
SpeedControl_ Average	Pearson Correlation	.395	.435	1	
	Sig. (2-tailed)	.000	.000		
	N	149	149	149	
Usefulness_ Average	Pearson Correlation	.365	.403	.612	1
	Sig. (2-tailed)	.000	.000	.000	
	N	149	149	149	149

Test of Research Questions - Regression Analyses

The researcher used stepwise regression analyses to relate the independent variables to the dependent variables in order to answer the research questions. Regression was performed on the whole sample first and the results analyzed. Table 9 summarizes the regression models when the sample is taken as a whole.

Table 4. 13 Summary of Stepwise Regression Models for Whole Sample

Dependent Variable/Model		R^2	R^2 Change	Sig. F Change	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
					B	Std. Error	Beta		
PerfCW	(Constant)	0.164			-4.274	5.703		-0.749	0.455
	SpeedControl_Average		0.119	0.000	6.405	2.082	0.253	3.077	0.002
	Source_Average		0.045	0.006	4.77	1.696	0.232	2.813	0.006
PerfExam	(Constant)	0.155			-20.076	10.473		-1.917	0.057
	Source_Average		0.117	0.000	9.711	3.115	0.258	3.118	0.002
	SpeedControl_Average		0.038	0.011	9.819	3.823	0.213	2.568	0.011
PerfOverall	(Constant)	0.167			-24.588	15.675		-1.569	0.119
	Source_Average		0.122	0.000	14.611	4.662	0.258	3.134	0.002
	SpeedControl_Average		0.045	0.005	16.153	5.721	0.232	2.823	0.005

To answer the main research question: To what extent do students' epistemological beliefs about mathematics predict their mathematics performance? The researcher sought to answer four related research question, The first one was: To what extent do students' epistemological beliefs about source of mathematics knowledge, predict their mathematics performance?

Table 10: Whole Sample Significant Regressions: Independent Variable - Belief about Source of Mathematics Knowledge with the Dependent Mathematics Performance Measures

Regression/Dependent Variable	R^2 (Explained variance)	B	Beta	t	Sig.
PerfCW: Course Work Score	.045 (4.5%)	4.77	0.232	2.813	0.006
PerfExam: Exam Score	.117 (11.7%)	9.711	0.258	3.118	0.002
PerfOverall: Overall Performance Score	.122 (12.2%)	14.611	0.258	3.134	0.002

The one way ANOVA indicated that there was no difference in the levels of the means of Source_Average (which measured belief about source of mathematics knowledge) for any of the sorting variables: gender, subject major or age (see Table 4.7). The regression analyses used the whole sample. The stepwise regression procedure revealed that Source_Average was a significant predictor of all measures of mathematics performance. The performance measures were: PerfCW – students' coursework score, PerfExam – students' scores in the final examination, and PerfOverall – students' overall scores in Calculus course. Table 10 shows the dependent variables, the R^2, B and Beta coefficients and their significance in the regression models.

For example, the stepwise regression model indicated that Source_Average alone accounted for 12.2% of the variance in PerfOverall_Average. Further, the regression procedure returned values for B and Beta as 14.611 and 0.258 respectively for the predictor variable Source_Average. The value B=14.611 means that a change of one unit in Source_Average accounted for a change of 14.611 in the PerfOverall_Average value. The value Beta=0.258 means that a change of one unit in the variance of Source_Average accounted for a change of 0.258 in the variance of PerfOverall_Average. The p-value (p=0.000) for the coefficients of the regression model B=14.611 and Beta=0.258 indicate that they are significantly greater than zero.

The researcher next sought to answer a second related research question: To what extent do students' epistemological beliefs about structure and stability of mathematics knowledge, predict their mathematics performance? The stepwise regression procedure, when applied to the whole sample, indicated that for all measures of mathematics performance, StuctureStability_Average (which measured beliefs about the structure and stability of mathematics knowledge) was not a significant predictor.

The researcher next sought to answer a third related research question: To what extent do students' epistemological beliefs about speed and control of mathematics learning, predict their mathematics performance? The stepwise regression procedure when applied to the whole sample indicated that for all mathematics performance measures, beliefs about the speed and control of mathematics learning, was a significant predictor of students' mathematics performance. Table 11 shows the dependent variables, the R^2, B and Beta coefficients and their significance in the regression models for the whole sample.

Table 11 Whole Sample Significant Regressions: Independent Variable - Speed and Control of Mathematics Learning with the Dependent Measures

Regression/Dependent Variable	R^2 (Explained variance)	B	Beta	t	Sig.
PerfCW: Course Work Score	0.119 (11.9%)	6.405	0.253	3.077	0.002
PerfExam: Exam Score	0.038 (3.8%)	9.819	0.213	2.568	0.011
PerfOverall: Overall Performance Score	0.045 (4.5%)	16.153	0.232	2.823	0.005

For example, SpeedControl_Average alone accounted for 11.9% of the variance in ActualPerfCW. Further, the regression procedure returned values for B and Beta as 6.405 and 0.253 respectively for the predictor variable Speedcontrol_Average. The value B=6.405 means that a change of one unit in SpeedControl_Average accounted for a change of 6.405 in the ActualPerfCW value. The value Beta=0.253 means that a change of one unit in the variance of SpeedControl_Average accounted for a change of 0.253 in the variance of ActualPerfCW. The p-value (p=0.002) for the coefficients for the regression model B=6.405 and Beta=0.253 indicate that they are significantly greater than zero.

Finally the researcher sought to another a fourth related research question: To what extent do students' epistemological beliefs about the usefulness of mathematics predict their mathematics performance?

The stepwise regression procedure, when applied to the whole sample, indicated that Usefulness_Average (which measured students' beliefs of about the usefulness of mathematics), was not a significant predictor of students' mathematics performance.

IV. Discussion

In this section the researcher summarizes the key findings as they relate to the main research question: To what extent do students' epistemological beliefs about mathematics predict their mathematics performance? The researcher next discusses possible explanations of the research findings, presents conclusions, implications, and some recommendations for educational practice.

The first related research question was: To what extent do students' epistemological beliefs about source of mathematics knowledge, predict their mathematics performance? From the analyses of data, the overall mean for Source_Average (which measured students' beliefs about the source of mathematics knowledge on a scale of 1 to 4) was 2.23 (refer to Table 3). This relatively low value for the mean indicated that the students in the sample lean towards the naïve belief that the teacher was the source of mathematics knowledge (in contrast to the sophisticated belief that mathematics knowledge could be constructed by the student through logic and intuition). The One Way ANOVA procedure revealed that there was no significant difference in the means for Source_Average for any of the groups in the sorting variables: gender, subject major and age (refer to Table 4). Regression analyses of data also revealed that students' belief about the source of mathematics knowledge was a consistent positive predictor of all measures of mathematics performance (refer to Tables 9 & 10). However, the research findings related to belief about the source of mathematics knowledge should be interpreted with caution since the reliability of the scale was below 0.7.

The regression analysis indicated that belief about source of mathematics knowledge is positively predicted all measures of performance measures. This research finding is similar to the findings of Szydlik (2000), but there were differences in methodology. Similar to the present research Szydlik (2000) conducted her study among undergraduate Calculus students. However, she used a mixture of quantitative and qualitative approaches to ascertain students' belief about source of mathematics knowledge, and performance. She used a paper and pencil questionnaire with multiple choice and likert-scale response to provide a rough measure of content beliefs and sources of conviction and a context for dialogue with students about their beliefs. The performance of the students was measured by a set of calculus problems to be solved and their solutions explained, and they were questioned by the researcher. Her finding though, is similar in that she found that students who had sophisticated beliefs about source of mathematics knowledge (she used the term 'internal sources of conviction') performed better. The finding in the present research with regard to belief about source of mathematics knowledge is also similar to Buehl and Alexander's (2005) study of undergraduate students. Similar to the present research, belief about source of mathematics knowledge was measured by use of a survey. Also similar is the use of a quantitative approach to measure performance (multiple choice test). Buehl and Alexander (2005) found that students who believed more in 'authority as the source of knowledge' had lower levels of motivation and task performance.

Garafalo (1989) provided some insights about how belief in the source of mathematics knowledge might influence student performance. Students who have the naïve belief that the teacher is the source of mathematics knowledge will likely tend to curtail their own comprehension of mathematics by relying only on what is presented by the teacher. The depth to which they explore/understand/apply a mathematics topic may often be limited by the extent to which the teacher explores/understands/applies the concepts in a particular topic. On the other hand, students that have the sophisticated belief that they could construct their own knowledge of mathematics tend to have a more exploratory approach to mathematics topics; such students may tend to reflect on and develop their own ideas, methods/strategies; they may tend to search for patterns and make generalizations, connections, applications beyond what the teacher presented. The foregoing may explain the positive prediction of performance by source of math knowledge in the present study.

The second related research question was: To what extent do students' epistemological beliefs about structure and stability of mathematics knowledge, predict their mathematics performance? The overall mean for StructureStability_Average, which measured students' beliefs about the structure and stability of mathematics knowledge, on a scale from 1 to 4 was 2.88 (refer to Table 3). This result indicated that overall, students lean towards the sophisticated beliefs that mathematics knowledge is made up of interrelated concepts that are constantly evolving (in contrast with more naïve beliefs that mathematics is made up of isolated bits of facts that are unchanging). The One Way ANOVA procedure found that with regard to StructureStability_Average, there was no difference in levels of the mean for any of the levels of the groups in the sorting variables gender, subject major, and age. Regression analyses showed that StructureStability_Average was not a good predictor of mathematics performance since it could not be used to predict any mathematics performance measure when the sample was taken as a whole (refer to Table 9).

When the sample is taken as a whole, the regression analysis indicated that beliefs about the structure and stability of mathematics knowledge did not predict any measure of performance. The reason for exclusion was not multiple collinearity. The correlation with the other independent variables were far less than 0.7 (see Table 8). It appears that for the students in the sample, there is no linear relationship between beliefs in structure and stability of mathematics knowledge and mathematics performance.

Xiao et al.'s (2009) findings are similar to those in the present study. Those researchers found a significant relationship between beliefs in the structure of mathematics knowledge and achievement in higher grade levels. However, they found no significant relationship between beliefs about stability of mathematics knowledge and achievement in any of the grade levels. Xiao et al. (2009) conceded that their findings were different from Western research results, in that epistemological beliefs did not predict mathematics achievement very well. They concluded that even though some dimensions of epistemological beliefs did predict mathematics achievement, the prediction seemed indirect, through affect, motivation, behaviour and cognition as the media. They also pointed to their methodology, explaining that a stepwise regression analysis probably was not adequate to explore the influences, which required more appropriate approaches, such as structure equation modelling. Also they claimed that the inconsistency with the Western findings may be interpreted as social culture and research difference.

The researcher cannot be conclusive about whether the methodology used in the present research was not sufficient to uncover the relationship between belief about the structure and stability of mathematics knowledge and achievement. The reason for the inconclusiveness is that in the studies of Buehl and Alexander (2005), and Koller (2001) their method for collecting data was similar to the present research, but their method of analyses differed. Buehl and Alexander (2005) used cluster analysis, while Koller (2001) used path analysis to uncover relationships between beliefs about the structure and stability of mathematics knowledge and performance. However Steiner (2007) used a similar methodology in data collection and analyses as the present research and found that beliefs about structure and stability predicted performance of university students. More studies might be able to determine the best method of analyses that could uncover possible relationships between structure and stability of mathematics knowledge and performance.

The result of the regression analyses may also be explained by the type of assessment used in the Calculus course. An examination by the researcher of the assessments used for coursework (quizzes) and for the final examination revealed that many of the questions required students to recall standard results and use them. Even the application problems replicated closely those found in the textbook/worksheets. These kinds of assessments may tend to result in students who have the naïve belief that memorizing lists of standard derivatives/integrals constitutes a good strategy for understanding calculus. These students may perform as well as students who have more sophisticated beliefs. Most of the questions in the assessments involved a single answer and by memorising a single procedure students can arrive at the solution. Again, these kinds of assessments may not help in distinguishing students with naïve beliefs about mathematics knowledge who are more likely to search for a single answer to a question, and who may expect there to be only one path toward the solution, from those who have sophisticated beliefs that mathematics knowledge is complex and tentative and may search for more complex answers and may anticipate various solutions.

The third related research question was: To what extent do students' epistemological beliefs about speed and control of mathematics learning, predict their mathematics performance? The overall mean for SpeedControl_Average, which measured students' beliefs about the speed and control of mathematics learning, on a scale from 1 to 4 was 2.87 (refer to Table 3). This value of the mean indicated that students lean towards sophisticated belief that mathematics learning takes time and effort and anyone can learn mathematics once he/she put in the time and effort (contrasted with the naïve belief that mathematics should be learned fast and only the gifted can learn it). The One Way ANOVA procedure indicated that with regard to SpeedControl_Average, there was no difference in levels of the mean for all groups in the sorting variables: gender, subject major, and age (refer to Table 6).

When the sample is taken as a whole, the regression analysis indicated belief about speed and control of mathematics learning predicted all measures of actual performance (refer to Tables 9 & 11). The positive relationship between belief about the speed and control of mathematics learning and actual performance found in the present and cited studies may be explained in terms of the time and effort students are willing to spend on mathematical tasks. Students who have the naïve belief mathematics should be learned quickly, may set a maximum time they will engage in a particular task without regard for the complexity or difficulty of the task. In addition, these individuals may believe that very little time is required for studying mathematics. In contrast, students who have the sophisticated belief that mathematics learning takes time are more likely to examine the material or problem and then decide how much time is needed. Time invested will be estimated but will be modified during the studying process depending on progress toward understanding. If performance measures also reflect the appropriate timing required for mathematical tasks, this appropriate timing of assessments may tend to result in the positive relationship between belief about speed and performance (Schommer, 1993).

Research has shown that instructional strategies can influence the beliefs of students (Muis, 2004). Therefore, lecturers may also contribute to beliefs students have about speed of mathematics learning. If lecturers constantly give students mathematical tasks with a time limit of perhaps 10 minutes or less and then the answers are revealed/discussed, students may come to think that mathematics is something to be done quickly. On the other hand, if lecturers often give mathematical tasks that allow adequate amount of time for analysis and solution by students and/or explicitly express that such tasks call for greater time to analyse/solve, this practice may contribute to the development of the sophisticated belief that mathematics learning takes time. It is evident from the finding of this research that lecturers at the university under study are employing instructional strategies that are fostering the development of sophisticated beliefs about the speed of mathematics learning. Of course, when lecturers allocate appropriate time to complete mathematical tasks according to their complexity, a positive relationship may likely exist between belief about the speed of mathematics learning and performance, as seen in the findings of the present research.

The positive relationship between belief about the speed and control of mathematics learning and actual performance found in the present and cited studies may be explained in terms of the effort students are willing to expend on mathematical tasks. Beliefs about the control of learning are likely to influence interpretations of mistakes and persistence in the face of difficulty while problem-solving. Students who have the naïve belief that only gifted people can do mathematics are more likely to believe that mistakes reflect their inadequacy. These persons are more amenable to performance learning, quite characteristic of our educational system, where grades are important. A minimal passing grade may be all for which these students strive. Such students may feel more frustrated and may be more likely to quit in the face of difficulty. On the other hand, students with the sophisticated belief that with much effort they can learn mathematics may be more persistent problem-solvers. They may tend to see mistakes as opportunities to learn. They may experience an increased intensity of interest in studying or problem solving, and they may attempt different study strategies rather than simply giving up in the face of difficulty (Schommer, 1993). These persons are mastery learners (Slavin, 1987). The findings of the present research indicate that students at the university where this study was conducted are developing sophisticated beliefs about speed and control of mathematics learning.

Previous research that investigated the relationship between belief about speed and control of mathematics learning and mathematics performance had mixed results. Schommer-Aikins, Duell, and Hutter (2005) did not find direct relationship between belief about speed and control of mathematics learning and mathematics performance. However, they found that beliefs about the speed and control of mathematics learning were related to general epistemological beliefs about speed and control of learning, and this result in turn predicted mathematics performance. The method to collect data in that study was similar to the present research. However, the positive relationship between belief about speed and control of mathematics learning and performance was found using a different approach to analyse the data (path analysis). Nevertheless, the outcome basically was the same.

In another study Schommer-Aikins and Duell (2013) investigated the way in which epistemological beliefs influenced mathematical problem solving at the college/university level. The study found that the domain-specific belief 'mathematics takes time and is useful' had direct and indirect effects on mathematical problem solving performance. Specifically, the more students believed that mathematics took time and was useful (sophisticated belief about speed of mathematics learning), the greater was their cognitive depth, and the better was their mathematical problem-solving performance. Schommer and Duell further found that the scale 'mathematics takes time and is useful' had an indirect effect on mathematical problem-solving as it was mediated via cognitive depth. In the study factor analysis led to the confounding of speed of mathematics learning with usefulness of mathematics (the scale used was mathematics takes time and is useful). Therefore it was not possible to determine the extent to which the questions related to speed of mathematics learning independently contributed to the performance measures. Nevertheless, similar to the present research, the authors were able to establish that speed of mathematics learning was somehow related to performance.

However, some studies obtained different results from the present research. In the study by Mason (2003) mixed results were obtained. The present research found that the more students believed that mathematics took time, the better were their mathematics grades. However, Mason found that belief about the control of mathematics learning did not predict mathematics performance. One possible interpretation she offered was that perhaps while students were aware that hard work was effective, they were not motivated enough to put in the hard work. In the study by Xiao et al. (2009) the researchers also did not find significant relationship between this scale and the grades of students.

The fourth related research question was: To what extent do students' epistemological beliefs about the usefulness of mathematics predict their mathematics performance? The overall mean for Usefulness_Average (which measured students' beliefs about the usefulness of mathematics on a scale of 1 to 4) was 2.86 (refer to Table 3). This value for the mean indicated that the students have a leaning towards sophisticated belief that mathematics is useful in their study of the other sciences, their everyday lives and their future work (in contrast to the naïve belief that mathematics is not useful). The One Way ANOVA procedure indicated that for Usefulness_Average, there was no difference in the levels of the mean for all the groups by sorting variables gender, subject major, and age (refer to Table 7). The regression analyses, when performed on the whole sample, indicated that Usefulness_Average did not predict any of the actual mathematics performance measure (refer to Table 9).

When the sample is taken as a whole, the regression analysis indicated that belief about the usefulness of mathematics did not explain any of the actual performance measures. It is also possible that even though the students in the sample had fairly sophisticated beliefs overall (high mean of 2.86) about the usefulness of mathematics, the assessments for the course involved very little applications of mathematics. Therefore, whether students appreciated the utility of the mathematics they were learning or not did not affect their performance. The researcher examined the quizzes and final exam and found limited applications of calculus to real-world problems or to problems encountered in the other branches of science. Discussions with the lecturers for the calculus course revealed that the time to finish the course outline was limited and covering applications that appealed to all the subject majors in the class was a challenge. Therefore, it is likely that the assessments contained limited applications/purely mathematical applications.

There are a number of studies, though, that investigated the relationship between the belief in the usefulness of mathematics and actual performance. Mason (2003) used the scale, 'mathematics is useful for everyday life.' That study found that when the sample was taken as a whole, the belief that 'mathematics is useful for everyday life' was a positive predictor of students' mathematics performance. However, Mason found that as the grade level increased there was a linear decrease in belief in the usefulness of mathematics. She did not report disaggregating the sample and doing a regression for the fifth grade level (ages 18-19) which is closer in age to the sample used in the present research) to see whether usefulness of mathematics still predicted mathematics performance. Therefore it is not clear whether Mason's findings agreed/disagreed with the findings in the present research.

In the study by Schommer-Aikins, Duell, and Hutter (2005) involving middle school students,' mathematical problem-solving performance was positively predicted by the belief that mathematics was useful. In the Schommer-Aikins and Duell (2013) study among college students, the researchers also used a 'Mathematics Is Useful scale,' that assessed the degree to which students reported that mathematics was useful in their daily lives. The study found that the domain specific mathematical problem solving belief 'mathematics takes time and is useful' had direct effects on mathematical problem-solving performance. In the study by Schommer-Aikins and Duell factor analysis led to the confounding of speed of mathematics learning with usefulness of mathematics (the scale used was mathematics takes time and is useful). Therefore, it was not possible to say to what extent the questions related to usefulness of mathematics independently contributed to the performance measures. Therefore, the two cited studies, like the present research, did not provide a clear-cut relationship between usefulness of mathematics and performance.

V. Conclusion

In summary, this research found that certain epistemological beliefs were significant predictors of mathematics performance. The two most significant predictors of mathematics performance were beliefs about the source of mathematics knowledge and beliefs about the speed and control of mathematics learning. However, beliefs about the structure and stability of mathematics knowledge and beliefs about the usefulness of mathematics were not good predictors of mathematics performance.

Implications

The findings in this research have implications for educational practice. Generally, students in the population of the present research were found to have beliefs about the source of mathematics knowledge that would put them at a disadvantage to excel in mathematics (overall mean for Source_Average=2.23). When lecturers are believed to be the source of mathematics knowledge, students may tend to be heavily dependent on lecturers to present the entire content of the calculus course and other parallel mathematics courses through direct instruction. Efforts to use a more constructivist approach to "discover" mathematics will most likely meet with some opposition from students. Students will most likely blame lecturers for failure in mathematics courses instead of taking ownership and responsibility for their learning. Future students may most likely expect that lecturers at the first year of university use a direct approach to teaching mathematics courses.

At the level of high school, the curriculum guides and Caribbean Secondary Examinations Certificate syllabus for mathematics encourage a student-centred approach to teaching mathematics. However, the researcher, in his 12 years experience as a high school teacher and a practicum supervisor for high school teachers, has observed that student-centred approaches to teaching mathematics are rarely practised in high school. The likely implication of the paucity of student-centred approaches to teaching mathematics, is that high school graduates enter university with the naïve belief that the teacher is the source of mathematics knowledge, and not that a recursion from sophisticated to naïve belief has taken place as they enter university (Boyes and Chandler, 1992). At the university where this study was based, mathematics course outlines do advocate student-centred approaches to course delivery but the practice has been to have more teacher-centred instruction. This teacher-centred instruction only serves to stifle the development of students' epistemological beliefs with regard to the source of mathematics knowledge.

With regard to beliefs about structure and stability of mathematics knowledge the implication is that students tend to engage in more deep learning, instead of viewing mathematics learning only as the memorising of facts and formulas to be applied to routine textbook problems – a surface learning approach. They likely look for the relationships among concepts within a topic, course and even with other courses. This tendency to integrate concepts aids students' problem solving capability. Another implication of the prevalence of sophisticated beliefs about structure and stability of mathematics knowledge among students is that instructional strategies seem to stress derivations of formulae, alternative solutions to mathematics problems and applications of mathematics to practical problems. However, the lack of relationship between the quality of students' beliefs about structure and stability of mathematics knowledge and performance implies that lower and higher order thinking skills are likely not assessed by lecturers in a way that distinguishes students according to their level of belief.

The beliefs of students regarding speed and control of mathematics learning implies that students know that their performance will likely be enhanced by better study strategies and efficient organization of their time. They are likely not discouraged when they fail to solve mathematics problems in a short time but are more persistent in the face of difficulty. The belief held by students that mathematics learning takes time and effort means that lecturers assign tasks to students and allow enough time for students to study a problem and to strategize their approach thus encouraging persistence in problem solving.

The beliefs of students regarding the usefulness of mathematics implies that students in the sample are more pragmatic. Pragmatic students tend to respond well to learning when they perceive relevance to their practice, and practical application for their learning. This recognition of the applicability of mathematics means that these students will tend to be more motivated in their study of the subject. Interest and engagement with the subject content will tend to be high.

The beliefs of students about the usefulness of mathematics also implies that the course content and instruction emphasize the applicability of mathematics to real-world problems. However, the lack of relationship between students' beliefs about usefulness of mathematics and their performance implies that assessments likely do not stress the application of mathematics.

Recommendations

The researcher presents recommendations based on the evidence presented in this research with regard to the relationship between students' epistemological beliefs and their learning/performance.

The Mathematics Department of the university under study, through professional development session/s, should help lecturers acquire knowledge of the educational implications of epistemological beliefs. These professional development sessions should consider research findings that underscore the importance of epistemological beliefs and their effects on students' mathematics performance.

The Mathematics Department of the university under study should seek to measure students' beliefs about mathematics as they enter and progress through their studies using a domain specific instrument. A number of instruments are available; the one by Wheeler (2007) used in the present research is a fairly reliable one (overall Cronbach alpha >0.7).

Once these beliefs have been assessed, instruction should be planned and implemented in the classroom to gradually change students' naive belief about the nature and acquisition of knowledge in mathematics. For example, in order for students to develop more sophisticated beliefs about the source of mathematics knowledge, lecturers need to move away from the traditional teacher-focused pedagogy to the constructivist learning framework that is student-focused. Similarly, to foster the development of sophisticated beliefs in other dimensions, lecturers need to conduct mathematics courses in way that highlights the interrelatedness and evolving nature of mathematics concepts, that mathematics takes time and effort and that mathematics is useful.

Another area that needs attention by lecturers in the Mathematics Department of the university under study is assessment of mathematics performance. It is very important that lecturers in creating assessments show recognition of the epistemology of mathematics learning, and their assessments reflect this recognition. Lecturers should set assessments that demand lower and higher order thinking skills in a way that distinguishes students according to their level of belief. These assessments will now provide appropriate feedback to both lecturers and students, and this feedback could then be used to further encourage students' epistemological development through appropriate instructional strategies.

With regard to further research, the researcher recommends that the mathematics epistemological belief structure of high school students in Guyana should be investigated and related to their performance. Assessment of high school students' beliefs may help to ascertain the epistemic levels that exist at the high school level and whether students tend to regress in their beliefs on entering university as Boyes and Chandler (1992) found. Also, the progressive development of epistemological beliefs may be assessed using an appropriate instrument (such as the one used in this study) at the university under study and their relationship to performance investigated.

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