THE STATISTICAL EVIDENCE IN DESCRIBING THE STUDENTS' BELIEFS ABOUT MATHEMATICS

Lazim, M.A, Abu Osman, M.T. & Wan Salihin, W.A
University College of Science and Technology Malaysia, 21030 Kuala Terengganu, Malaysia

ABSTRACT: *This article describes a statistical study of students' beliefs about mathematics. An instrument was developed from the theoretical considerations of views about mathematics and the components of beliefs in teachers-students interactions. This instrument distributed to two hundred and fifteen Form 5 students from three fully residential secondary schools in Peninsula Malaysia. A factor analysis of respondents identified four factors of students' beliefs about mathematics. Eight of the items converged at the first factor which was recorded highly on loading. Correlations indicated that students tend to belief about the role of teachers modestly commensurate with the beliefs about the usefulness of mathematics. The four factors recorded very high reliability of internal consistencies. Withstanding the analysis done, this four-factor instrument is just a beginning in inspiring the more reliable and upgraded instrument.*

INTRODUCTION

At layman's glance, the word mathematics probably gives a very simple meaning which reflecting the use of numerical values and its arithmetic operations. However the meaning of mathematics is just not merely restricted to arithmetic operations but can be more broadly defined. However, many people do not seem to be very interested in talking about mathematics and the way mathematics will be learned. It is very hard for the public to even name well-known mathematicians. It also seems difficult for the public and even school children to distinguish clearly between mathematics with other science-based subjects.

The uniqueness of mathematics and the reluctance of people to go in-depth about mathematics seem related to the way they perceive and believe what mathematics is all about. A belief about something will adversely generate other psychological domains of behaviour. In the same way, belief about mathematics can determine how one chooses to mentally construct the whole idea of mathematics. This is especially true when the belief has been put in the world of mathematics students. Beliefs are personal principles, constructed from experience that an individual employs, often unconsciously to interpret new experiences and information and to guide action (Pajares, 1992). Actions taken by students during learning processes have greatly affected the knowledge acquisition of mathematics. Cobb (1986) defined beliefs as an individual's personal assumptions about the nature of reality.

The importance of beliefs in the life of a student is stressed again because these assumptions constitute the goal-oriented activity.

Beliefs play a significant role in directing human's perceptions and behaviour. Almost two decades of research revealed how students' beliefs shape their cognitive and affective processes in the classroom. In learning environments, students' belief might propagate the idea for achievements and smoothness of learning. In the mathematics learning process, student's belief about the nature of mathematics and factors related to the learning are two components that always concern mathematics educators.

THEORETICAL CONSIDERATIONS

The psychological system of belief based on the philosophy of the view of mathematics becomes the main source of theoretical background discussed in this paper. Ernest (1994) outlined three philosophies about the views of mathematics. Firstly, there is the instrumentalist view that mathematics is an accumulation of facts, rules and skills to be used in the pursuance of some external end. Thus mathematics is a set of unrelated but utilitarian rules and facts. The second view is the Platonist view of mathematics as a static but unified body of certain knowledge. Mathematics is discovered but not created. Thirdly, there is the problem solving view of mathematics as dynamic, continually expanding field of human creation and invention, a cultural product. Mathematics is a process of enquiry and coming to know, not a finish product, for its result remain open to revision. These views ground the main platform of the nature of beliefs about mathematics regardless of the categories or strata of human beings including the lives of students.

Furthermore, the nature and structure of belief indicated that students' belief depend largely on their social lives. Bounded social historical context of students' lives will determine the directions of belief. In their world, the students will interpret its rules and practices on the basis of their prior belief and knowledge and as such develop their own, to a large extent shared, conceptions about it (Cobb & Yackel, 1998). Knowledge and beliefs operate to form schemas or mental models which regarded as the highest order constructs. These constructing processes are operates within the students' consciousness in the bounded social context to form various categories of beliefs.

In addition, McLeod (1992) has suggested four categories of students' beliefs. The first category, beliefs about mathematics, includes beliefs such as thinking that mathematics is difficult or that it is based on rules. The second category, beliefs about self, includes self-confidence in learning mathematics and attributions for success and failure in mathematics. The third category, beliefs about teaching, includes beliefs about what a teacher should do to help a student learn mathematics. McLeod's fourth category is beliefs about social context. This category includes the beliefs that mathematics learning is competitive and that parents and others outside that school have a significant influence on one's mathematics learning. McLeod's (1992) categories are useful in that they lead to consideration of the wide variety of beliefs that students have and the potential effects of those beliefs on learning.

As a summary of philosophic views of mathematics and the students' belief suggested by McLeod (1992), one model of students' beliefs about mathematics could be drawn. Students' beliefs about mathematics possibly could be analysed into four dimensions which anticipated as interrelated and functioning concurrently in a system to construct mental models. Students' beliefs seem to point to their way of learning and role of teachers that are their classroom, themselves and mathematics as another object of belief. The dimensions of student's belief can be represented as shown in the Figure 1.

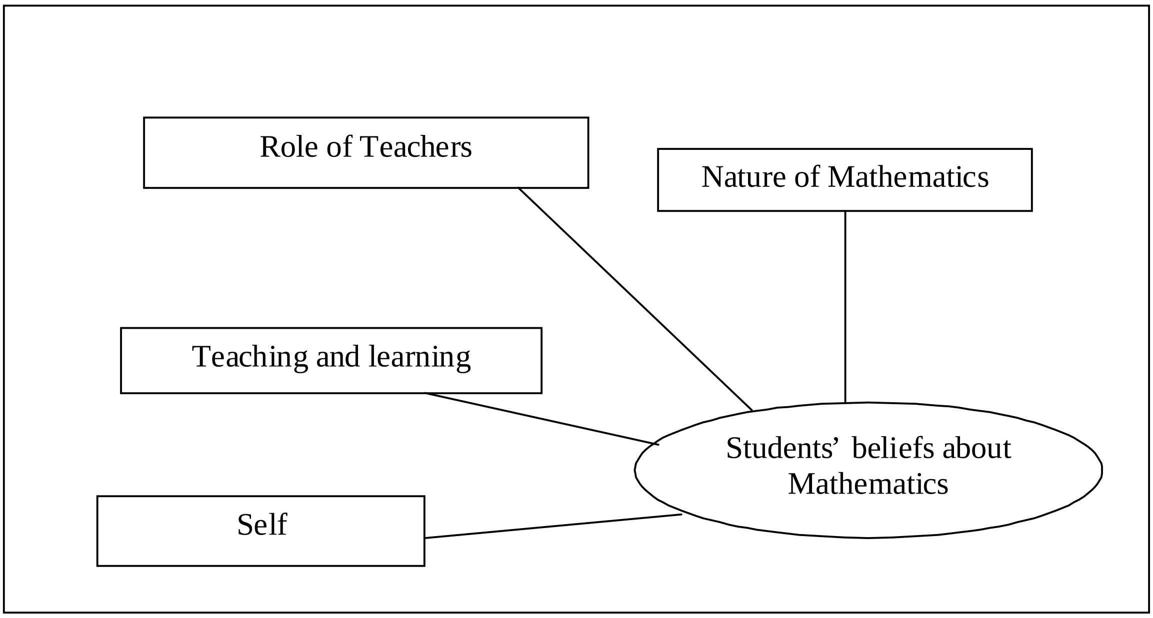

Figure 1. Students' Mathematics-Related Beliefs

From the above figure, students' belief about mathematics can be constituted as Beliefs About the Nature of Mathematics, Beliefs About the Way of Learning and Teaching Mathematics, Beliefs About Their Competency and Beliefs About Their Respective Teachers. The dimension of belief about self refers to their performance in mathematics and when their interest of mathematics started. Within the students' beliefs about social context restricted to the belief about the role and the functioning of the teachers. The dimension of belief about nature of mathematics could be broad to the utility aspect of mathematics.

This conceptual model of student's belief is based on the knowledge of the nature and function of beliefs. Indeed, Schoenfeld (1983) advocated that different dimensions of beliefs can determine a person's cognitive actions. He singled out cognitive actions which are often the result of unconsciously held beliefs about the task at hand, the social environment within the task takes place and the individual problem-solvers' perception of self and his or her relation to the tasks and the environment.

PROBLEM STATEMENTS

More than twenty years ago, Schoenfeld (1985) tossed the idea of mathematical system belief and its implication to the mathematical problem solving. The significance of belief toward mathematics was concerned and shared by Lampert (1990). He reported that many students appear to hold a lot of naïve and incorrect beliefs about mathematics. If this happened, it would jeopardise the whole idea of learning mathematics and eventually will create slackness in a midst of preparing people in the era of information technology.

Although generally most people agree with the importance of mathematics in daily life and its usefulness in career but these people are very reluctant to talk about mathematics. In Malaysia, the interest of mathematics among school children is in decreasing mode. Lim (2002) reported that research done by Lee et al in 1996 found that science and non science student's ratios have deteriorated from 31: 69 in 1986 to 20: 80 in 1993. It is a drop of 11% in number of students taking science-based subjects. The most common reason as quoted by 58% of 766 Form 4 students and 59% of 489 Form 6 students for not choosing science subjects was the poor foundation in science and mathematics. The other common reason was no sense of confidence in mathematics. The lack of confidence towards the interest in mathematics raised concerns from all related parties to look into. Do the students really hold incorrect beliefs about mathematics?

Past research revealed how students' beliefs shape their cognitive domain in the learning processes. A study done by Lester, Garofalo & Kroll (1989) shows how belief about the nature of mathematics and mathematical learning and problem solving determine how one chooses to approach a problem and which techniques and cognitive strategies will be used. To study the beliefs about mathematical problem solving of junior high school students in the summer mathematics program for gifted students, Frank (1988) observed the 2-week program and conducted several interviews with the participants. In the interviews, Frank asked the students about the nature of mathematics and also asked them to think aloud when solving problems. Based on her observations and interviews, Frank concluded that even gifted high junior school students believe that mathematics is computation, that all problems can be solved in just few steps, that the goal of mathematics is to get the right answers, that the role of the mathematics students to receive mathematical knowledge, and that the role of a teacher is to transmit knowledge.

Apart from the research on the cognitive domain, there was also research done to show the impact of students' beliefs to motivation. More specifically, studies on students' value and expectancy beliefs in the context of mathematical learning and problem solving clearly show how these beliefs relate to the students motivation and problem solving skills (Kloosterman et al, 1996).

Most of the studies situated at the cognitive, motivational or affective research operate as separate cases from each other. The study of specific categories of beliefs gives impetus to engage in research of different categories of students' beliefs in relation to each other. Furthermore, teaching experiences and conversation with students indicated that there are many ideas about how well they like mathematics, why mathematics is important and how competent they are in mathematics. These various categories of beliefs and added with the signs of down-trend interest in mathematics are surely related to the learning and can significantly affect the behaviour of students in classroom. The relationship between these psychological factors in the learning process will be examined further by attempting to insert the statistical proofs on these categories of beliefs. Therefore, the main purpose of this study is to provide the statistical evidences in describing the students' related-mathematics beliefs as prescribed in the theoretical considerations.

METHODOLOGY

Instruments

In order to meet the research objectives, a mathematics belief questionnaire was constructed based on the outlined theoretical considerations. Basically, the questionnaire consists of four dimensions to represent four facets in student's beliefs. The dimensions include the belief about the nature of mathematics, about the role of teachers, about teaching and learning mathematics and about their competency in mathematics. Every factor consists of two or more items measuring the belief in score of a five point Likert-scale from 1 (strongly agree) to 5 (strongly disagree). In short, this questionnaire contains 19 items measuring four dimensions of beliefs about mathematics (see Appendix A).

Subjects

Two hundred and fifteen Form 5 students from three fully residential secondary schools participated in the study. Students are mixed in gender and scored 'A' in the mathematics subject in their Penilaian Menengah Rendah (PMR) public examination. Data was collected three months before students sat for their Sijil Pelajaran Malaysia (SPM) public examination.

DATA ANALYSIS AND RESULTS

A principle component analysis, correlations and reliability were performed on all the items. Results from the analysis are presented as factors to be retained, loading for each factor, correlations between factors and internal consistency of reliability, thus believed to be able to provide the statistical evidences in unravelling the students' beliefs about mathematics.

FACTORS TO BE RETAINED

Characteristics from the items of the instrument of beliefs which go together constitute a factor. Factor analysis refers to a number of related statistical techniques which help users to determine them. There are three main purposes of using the factor analysis technique as outlined by Bryman & Cramer (2001). First, factor analysis can assess the degree of which items are tapping the same concept. Second, factor analysis can determine the degree to which they can be reduced to a smaller set. The third use to which factor analysis was utilised is to make sense of the bewildering complexity of social behaviour by reducing it to a more limited number of factors. The first two purposes of factor analysis will be discussed further in this paper.

Prior to analysing data using factor analysis, data collected in this research went through Barlett's Test of Sphericity meant to measure the applicability of factor analysis. Kaiser-Meyer-Olkin Measure of Sampling Adequacy recorded at 0.718 (>0.5), hence it is good to use factor analysis in determining the number of factors to be retained and loading factors on the items.

Scree Plot

One of the main purposes of factor analysis is to reduce the number of variables to a smaller number. In this study, factor analysis is used to derive the new variables which are called factors hoped to give better understanding about data. A factor analysis is an analytical tool that can help us determine empirically how many construct or lantern variables or factors underlie a set of items (De Vellies, 1991). The graphical scree plot proposed by Cattel (1966) was used to reduce the number of factors from items in the instrument. In this method, graph is drawn of the descending variance accounted for by the factors initially extracted. Scree plot describes a guideline in extracting the number of factors. The factors to be retained are those which lie before the point at which the eigenvalues seem to level off. Cattel' s scree test – plotting the eigenvalues and looking to see where the graph tails to shallow scree (Child, 1970; Kim and Mueller, 1978; Norusis, 1990; DeVellis, 1991).

From the data collected, an analysis of the scree plot revealed that four items should be extracted. These items have the point at which the eigenvalues seem to level off. The four factors have eigenvalues greater than one (See Figure 2).

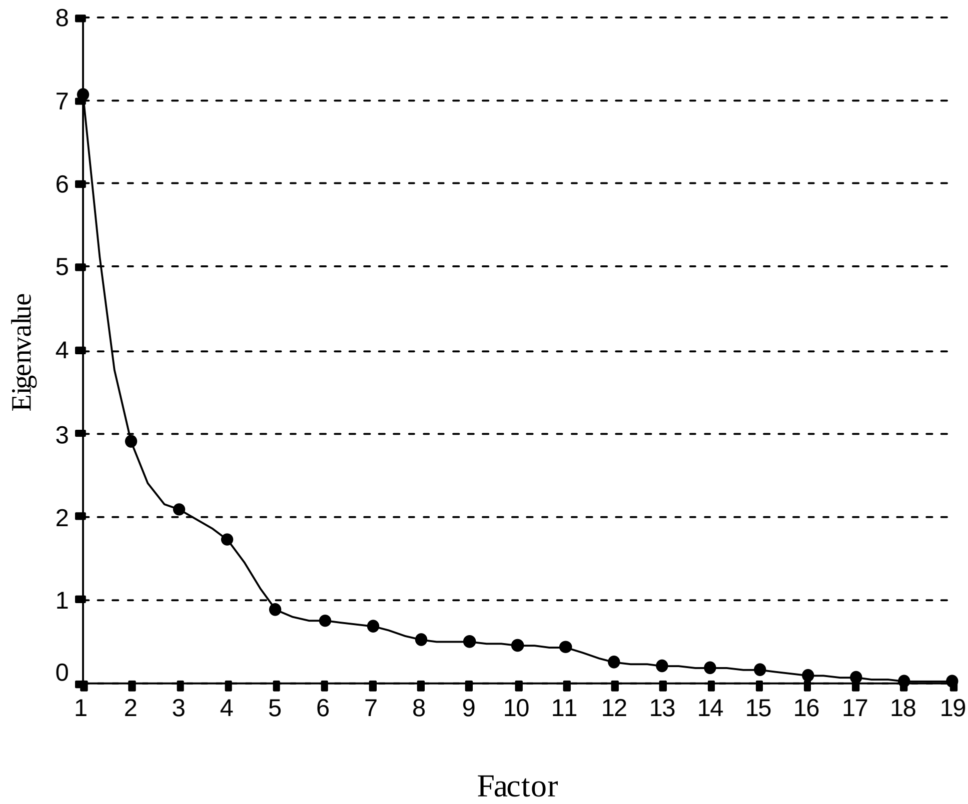

Figure 2. Scree Plot Diagram Showing The Eigenvalues of The Items

Kaiser's Criterion

The other criterion in deciding which factors to be excluded is Kaiser's criterion. In respect of determining the number of factors to be extracted, Thurstone (1974) recommends accepting those with eigenvalues in excess of 1-described by Child (1970) as the Kaiser criterion. Goddard & Kirby (1976) and De Vellis (1991) suggest that Kaiser criterion equates to accepting 'only those factors that account for more than their proportional share of the original variance' (Goddard & Kirby, 1976, p.24). As shown in Table I, there are four factors which have the eigenvalues more than one hence it was understandable that these four items could be extracted. The fourth factor recorded eigenvalue at 1.73 with 9.10% of variance and the first factors punctuated at 7.08 with 37.25% of variance.

Table 1. Initial Eigenvalues Of Factors And Their Variance

	Initial Eigenvalues		
Factors	Total	% of Variance	Cumulative %
1	7.078	37.252	37.252
2	2.889	15.207	52.459
3	2.086	10.981	63.440
4	1.729	9.102	72.542
5	.896	4.717	77.260
6	.760	3.999	81.259
7	.681	3.585	84.844
8	.522	2.748	87.592
9	.499	2.628	90.220
10	.434	2.287	92.506
11	.411	2.164	94.670
12	.248	1.308	95.978
13	.211	1.109	97.087
14	.184	.968	98.055
15	.157	.829	98.883
16	9.378E-02	.494	99.377
17	6.882E-02	.362	99.739
18	3.182E-02	.167	99.906
19	1.781E-02	9.376E-02	100.000

In this study a four factors solution was adopted as a sequence of both the Kaiser's criterion and a scree test. Four factors solution accounts for 72.54% of cumulative variance. Thus, it is rather a good set of construct to deal with and allow for the best interpretation.

LOADING FOR EACH FACTOR

Another main use of factor analysis is to measure the items that are representing the same concept. The items are then reduced to a factor to form a certain degree of correlation with a factor. The relationship between each item and a factor is expressed as a correlation or loading. In order to increase the interpretability of factors, they are rotated to maximise the loadings of some of the items. The two most commonly used methods are orthogonal rotation which produced factors that are unrelated to or independent of one another and oblique rotation in which the factors are correlated (Bryman & Cramer, 2001). Data from this study was analysed using orthogonal rotation since the factors are presumed unrelated.

Varimax with Kaiser Normalization

Process of orthogonal rotation of two principal-component factors is known as varimax. In this study, nineteen items were subjected to factor analysis (principle component with Varimax with Kaiser Normalization), which is a statistical technique to identify relatively small number of factors that can be used to represent relationships among a set of many interrelated variables (Norusis, 1990). A decision was taken, in the light of the experiences of others, to accept as valid contributors to a factor only those items with loadings in excess of 0.4 (DeVallis,1991; Woodrow, 1991; Kay, 1993). Details of the items comprising each factor, their loadings can be seen in Table II. It can be seen that three items loaded on more than one factor. In each case these items were included in both factors. Thus, for example, the statement 'Persistence with increasing variations leads understanding' contributed to both factors 1 and 2. This is a consequence of these items loading relatively weak on the stronger factors and strongly on the later or weaker factors.

Table II. Details of factor analysis showing the weightings of each item

Items	1	2	3	4
'Drill and practice' is one of the best ways learning mathematics	.753	.487		
Good mathematics teachers spark interest	.749			
Teacher gives us encouragement to work harder	.707			
My teacher contributed to my interest	.700			
I still remember well my good mathematics teachers	.693			
Mathematics is a field of manipulating symbols and numbers	.626			
Persistence with increases variations leads	.607	.547		

understanding				
Mathematics is a challenging subject	.562			
Mathematics enables men understand the world better		.886		
Symbols and equations used to model the world		.877		
Mathematic provides foundation for applied sciences		.852		
Mathematics is a way of thinking using symbols and equations		.842		
Mathematics is important in real life		.706		
I have been doing well in mathematics exam			.920	
I like mathematics			.849	
Mathematics is considered one of the difficult subjects			-.734	
Teacher really wants us to enjoy learning				.937
Teacher appreciates it when I tried hard				.927
I have been interested in math since primary school	-.428			.599

Items with the highest loading on Factor 1 is 'Drill and practice' is one of the best ways learning mathematics. This item is also shared by Factor 2. On Factor 2, the highest loading is 'Mathematics enables men understand the world better' followed by 'Symbols and equations used to model the world'. The item of self-confidence 'I have been doing well in mathematics examination' recorded the highest loading on Factor 3.

The amount or percentage of variance that each of the orthogonally rotated factors accounts for is shown in Table III.

Table III. Percentage Variance of Four Factors That Orthogonally Rotated

Rotation Sums of Squared Loadings		
Total	% of Variance	Cumulative %
4.477	23.564	23.564
4.354	22.914	46.478
2.664	14.020	60.498
2.285	12.026	72.523

It is shown that the variances for the first and second factors are not very different (about 23%). It is about 14% for the third factor and 12% for the fourth factor.

THE CORRELATIONS BETWEEN FACTORS

The correlations (Pearson's r) between different factors showed that students holding strong belief to their teachers and way of learning mathematics have modest correlation with their beliefs about the application of mathematics (r= 0.562). Nevertheless the correlations between other factors in this study showed either very low or low correlation. The guideline for the interpretation of the strength of correlation is based on the suggestion by Cohen and Holliday (1982). Details of the correlations between factors can be seen in Table IV. The figures printed in bold show the significant probabilities for the respective correlation.

Table IV. Correlations Between Factors

	Factor 2: Usefulness	Factor 3: Competency	Factor 4: Excellence
Factor1:Teacher and learning	.562	-.004	-.278
	.000	**.981**	**.050**
Factor2: Usefulness		-.022	-.275
		.881	**.053**
Factor 3: Competency			.115
			.428

INTERNAL CONSISTENCY OF RELIABILITY

Items in the questionnaire underwent the reliability analysis in accordance with the four factors extracted. The reliability coefficient tells the consistency of the questionnaire. The widely used Cronbach's alpha calculates the average of all possible split-half reliability coefficients. In this study, the Cronbach's alpha yielded acceptable ranges of reliability coefficients. The scale on students' beliefs about the usefulness of mathematics had a very high alpha (0.91), as did the scale on students' beliefs about the teachers' role and their way of learning mathematics. There was also a higher reliability (-0.81) on the students' beliefs about their competency in mathematics. Also noted a slightly lower coefficient (0.73) compared to the other factors was students' belief about their goal to bring excellence in mathematics. Taking all factors together, this instrument is highly reliable in measuring students' beliefs about mathematics and the related components. Results of the internal consistency of reliability for four factors are shown in Table V.

Table V. Results of Cronbach's Alpha Estimates

Factors	Number of statements	Alpha value
1: Teacher and learning	8	0 .8624
2: Usefulness	5	0.9100
3: Competency	3	-0.8061
4: Excellence	3	0.7339

CONCLUSIONS AND DISCUSSION

The factor analysis shows that there were four factors that could be extracted from the instrument. Clearly, the factors do not entirely constitute the whole theoretical considerations in system of belief. Despite the small factors extracted, the instrument seemed to cover the extensive items in the beliefs system as described in theoretical considerations. This four-factor instrument extracted was based on scree plot and Kaiser's criterion has shown very sound statistical evidence that could not be ruled out.

Statistical evidence goes further to strengthen the students' beliefs instrument about mathematics. The analysis of loading on each item has seen strongly converged on the first and second factor. Fourteen of the items have seen to form a new cluster segregated from the rests. The imbalance distributions should be looked positively as a room of improving and editing the items. In addition, the initial intention of the instrument is neither not purely to divide fairly among the items in respect of the underlying theoretical considerations nor to pre-emptive knowing the students' responses.

The first factor comprised of eight items formed a new cluster of two components of beliefs about the way of learning and the role of teachers. This finding falls within Mc Leod's (1992) category of beliefs about teaching. The clustering of these two components in one factor indicates that the students who positively accepted the importance of teachers are also the ones who are convinced about the best way of learning mathematics. The same explanation goes for the fourth factor which is the clustering of the teachers' expectation from the students and their competency in mathematics.

Despite the imbalanced number of items in each factor, it is a very good side to focus on the weight on every item. The importance of mathematics in every day life and the role of the teacher in learning processes is seen as very paramount in what the students constitute in beliefs about mathematics. It is obviously shown by the loading in first factor that the students hold strong beliefs that the teachers play a major role in contributing to their interest in mathematics. Further, the beliefs about the way that mathematics should be learned and studied are also not to be left out. The students are highly perceived that 'drill and practice' is a very important element in learning mathematics. The importance of 'drill and practice' also equally shared by Malaysian Mathematicians (Lim, 2002). Details and significance of every item are not meant to be discussed in this paper. Generally, statistical loading analysis on each item in this four-factor instrument will become a very helpful indicator in discussing the important element of students' beliefs about mathematics and eventually will boost the impact on the effectiveness of learning mathematics.

In spite of high loading recorded on every factor, the relationships between the factors are not obviously seen and are very hard to interpret. The only modestly correlation (Cohen & Holliday, 1982) is between the first and the second factor. The socio-constructivist view of mathematics (Ernest, 1991) in the second factor has positively correlated with the view of teaching and learning in the first factor. However the result of internal consistency for every factor shows a very convincing reliability.

Conclusively the overall analyses have shown a good support to the instrument in describing the students' belief about mathematics. McLeod's (1992) four categories of belief were fairly worked in this research though the instrument does not comprehensively account for the theoretical considerations. Further analysis and improvement of the instrument should be done rigorously in hopes to produce a more reliable and comprehensive tool.

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APPENDIX A: Questionnaire Beliefs About Mathematics

Please rate the following statements regarding the ways of beliefs about mathematics according to the following rating scale representing your degree of agreement or disagreement and circle your rating.

Strongly agree	1
Agree	2
Uncertain	3
Disagree	4
Strongly disagree	5

1. I have been doing well in mathematics.	1	2	3	4	5
2. I have been interested in mathematics since primary school.	1	2	3	4	5
3. Good mathematics teachers spark my interest in mathematics.	1	2	3	4	5
4. I still remember very well my good mathematics teachers.	1	2	3	4	5
5. Teacher gives encouragement to work harder.	1	2	3	4	5
6. My teacher contributed to my interest in mathematics.	1	2	3	4	5
7. Mathematics is a field of manipulating numbers and symbols.	1	2	3	4	5
8. Mathematics is important in real life.	1	2	3	4	5
9. Mathematics is a way of thinking using symbols and equations.	1	2	3	4	5
10. Mathematics is a considered one of the difficult subjects.	1	2	3	4	5
11. Mathematics is a challenging subject.	1	2	3	4	5
12. I believe ‘ drills and practice’ is one of the best ways of learning mathematics	1	2	3	4	5
13. Persistence with increases variations leads understanding.	1	2	3	4	5
14. Mathematics provides foundations for applied sciences	1	2	3	4	5

15. Symbols and equations used to model the world.	1	2	3	4	5
16. I like mathematics.	1	2	3	4	5
17. Mathematics enables men understand the world better.	1	2	3	4	5
18. Teacher really wants us to enjoy learning.	1	2	3	4	5
19. Teacher appreciates it when I tried hard.	1	2	3	4	5