An exploratory study of Brunei Darussalam pre-university students' affective mathematical modeling competencies

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1. Introduction

Affective (beliefs and attitudes) factors, seen as one of the main contributing factors to an individual's desires is as significant as being mathematically literate (cognitive). Many researchers have reported that positive beliefs and attitudes have been attributed to increase mathematical content knowledge. Thus, the aim of this exploratory study is to identify the beliefs and attitudes of Brunei pre-university students in relation to mathematical modeling. This will further assist in hypothesizing that students' stimulated beliefs towards mathematics will make them assertive in their attitudes towards a certain aspect of learning mathematics, in particular mathematical modeling.

2. The Affective domains

In the past three decades, there have been an increased interest and focus on mathematical affect (Walberg, 1984; McLeod, 1992; Wilkins & Ma, 2003; Grootenboer & Hemmings, 2007; Biccard & Wessels, 2011; Mata *et al*., 2012). Walberg (1984) identified nine factors that accounted for pupils' school learning in relation to academic achievement from a synthesis of nearly 3000 study comparisons: (a) student aptitude (prior knowledge, age and stage of maturation and motivation), (b) instruction (amount and quality of instruction), and (c) psychological environments (perception of classroom social group, home environment, peer influence and media exposure) (Walberg, 2003). Several research studies have consistently used these factors to envisage students' attitude as one of the contributing factors in mathematics and science achievement (Wilkins & Ma, 2003).

In 1992, McLeod re-conceptualized beliefs and attitudes towards mathematics, as the affective domain in mathematics education and instruction in three aspects: beliefs, attitudes and emotions. In his discussion, beliefs were categorized as beliefs about mathematics, about self, about mathematics teaching or mathematics classroom instruction, and the social context. From the perspective of beliefs about mathematics teaching and learning, Ernest (1988) distinguished three conceptions of mathematics: *the instrumentalist view, Platonist view and the problem-solving view*. The *instrumentalist view* looks at mathematics as a collection of facts, skills and rules with no connection. The *Platonist* view sees mathematics as a static body of knowledge, and the *problem-solving* view considers mathematics as dynamic with content continually growing (Allen, 2010). In her study, Allen asserted that teachers shift their views to be consistent with the problem-solving view in order to become effective teachers of mathematics. Similarly, for a student to be effective learner, one must view mathematics as a process of enquiry and exploration, not just a set of utilitarian set of facts and rules. The aspect of attitudes covers the positive and negative feelings of a learner towards a certain aspect of learning mathematics in two different ways, resulting either from automatizing a repeated emotional reaction or from assigning pre-existing attitude towards a new and unfamiliar task. Subsequently, the aspect of emotions considers the physiological arousal of a learner including fear, anxiety, embarrassment, panic and tension during a problem-solving process. Wilkins and Ma's (2003) study seemed to show that positive encouragement through the influence of teachers, peers and parents helped diminish the development of negative beliefs and attitudes.

Biccard (2010) employed both models from Walberg (1984) and McLeod (1992) in his study of presenting mathematical modeling tasks as collaborative works in developing mathematical modeling competencies in primary school learners. Analyses of his study revealed that the learners were highly motivated, fully engaged (time spent) on quality tasks and worked collaboratively as modeling tasks were introduced to stimulate their cognition and beliefs. It thus makes sense in this study to relate the affective domain of learners to Walberg's theory of educational productivity. Our study adapted the definition of affective modeling competencies by Biccard (2010) in relation to beliefs and attitudes valued by McLeod (1992), and focused on the significance of the two sets of Walberg's theory: *personal variables*, which include development (gender, age and learners' year group); and *environmental variables*, which include home environment (parental education level), availability of gadgets and media exposure (use of technology and gadgets).

In this exploratory study, we only made use of a questionnaire in identifying the affective competencies of Brunei pre-university students that describe their beliefs about mathematics, the ways they solve mathematics problems and the value of mathematics in relation to everyday life situations, mainly because mathematical modeling is not yet formally introduced at any school level in Brunei Darussalam. The results from this study can then be used to prescribe approaches and strategies in the integration of mathematical modeling as a problem solving approach in facilitating the learning of mathematics at the pre-university level.

3. Methods

3.1 Participants

A total of 183 pre-university students from one college answered the questionnaire. It must be noted however, that 16 of the participants (8.7%) had to be eliminated because of some missing information in their replies. The classes of students were heterogeneous in their disciplinal areas of study and have an age range of 16 – 20 years old (Mean = 17.8 years). The participants consisted of 96 female (57.5%) and 71 male (42.5%). All of the students were enrolled in the General Cambridge Certificate of Education (GCE) Advanced (A) level mathematics, which requires a minimum grade of C in the GCE Ordinary (O) level mathematics. Since the study was carried out in the final term of an academic year, all of the students have already covered all topics in their designated syllabus, which is a pre-requisite to the study. It must also be noted that the sample of students in this exploratory study had not taken any mathematical modeling training course or experienced modeling prior to completing the questionnaire. The questionnaire was carefully designed to include a wide range of different questions in order to identify the participants' affective competencies in describing their beliefs about mathematics, the ways they solve mathematics problems and the value of mathematics in relation to everyday life situations.

3.2 Instruments

The questionnaire was administered in the classroom by the students' respective teachers. The questionnaire was structured to focus on *personal variables* and *environmental variables* in identifying the students' beliefs in the learning of mathematics and attitudes towards mathematical modeling. The questionnaire consisted of 20 items distributed over six dimensions that focus on the affective factors and the rotated factor matrix. The 20 items instrument required the participants to indicate their response using a 5-point, Likert-type scale ranging from *never* = 1 to *always* = 5. The items were coded with the higher score reflecting more positive views, and analyzed using SPSS v.20. The reliability score for the 20-item instrument is in the acceptable range of Cronbach's Alpha value 0.77. The results are confirmatory with all the 20 items as they fit all the six dimensions (refer to Table 1).

Table 1. The rotated factor matrix.

Items	**Six Dimensions of learners' views (factors)**					
	1	**2**	**3**	**4**	**5**	**6**
1. Thinks mathematics is useful in everyday life.	.861					
2. Thinks that mathematics is used in everyday life.	.893					
3. Uses mathematics in everyday life.	.812					
4. Thinks mathematics will help in future career path.	.551					
5. Finished all assigned mathematics homework at home.		.786				
6. Looking forward to a mathematics lesson.		.623				
7. Very keen to learn new ideas and theories in mathematics.		.594				
8. Thinks mathematics is fun to learn.		.550				
9. Work individually to solve mathematics questions.			.737			
10. Learns mathematics through understanding and problem-solving strategies.			.666			
11. After completing a mathematics question, you try to interpret the solution.			.437			
12. I usually do well in mathematics.			.673			
13. Seeks help from a mathematics tutor.				.569		
14. Seeks help from peers (discussion to seek mathematical solutions).				.775		
15. Works in a group to solve mathematics questions.				.728		
16. Learns mathematics through memorizing of formulae and procedures.					.507	
17. Thinks mathematics is all about solving equations (numerical computation).					.845	
18. Thinks mathematics solution is just a numeric without much meaning.					.574	
19. Curious about the mathematical solution obtained.						.604
20. Uses Internet to search for mathematical solution.						.707

Notes: Corresponding dimensions *1. Attitudes towards mathematical modeling, 2. Positive beliefs, 3. Self-beliefs, 4. Attitudes towards social context, 5. Instrumentalist beliefs and 6. Use of technology in learning mathematics.*

4. Results and discussion

The results focus on two main directions: descriptive statistics of participants' affective domain (beliefs and attitudes) towards the value of mathematics in solving real-life situations in considering the personal variables, and environmental variables. Secondly, the bivariate correlation analysis was performed to examine relations among the affective domain in the six dimensions and the personal and environmental variables.

Table 2. Description of variables.

Variables	**Mean (SD)**	**Description**
Age of Student	17.8 (.89)	The age range of students was from 17 to 20 years old.
Attitudes towards mathematical modeling	4.09 (.76)	Composite of 4 items related to attitudes towards mathematical modeling.
Positive beliefs	3.74 (.70)	Composite of 4 items related to positive beliefs.
Self-beliefs	3.63 (.56)	Composite of 4 items related to self-beliefs.
Attitudes towards social context	3.29 (.66)	Composite of 3 items related to attitudes towards social context.
Instrumentalist beliefs	3.28 (.72)	Composite of 3 items related to instrumentalist beliefs.
Use of Technology	3.11 (.78)	Composite of 2 items related to use of technology.

Note: Means and standard deviations are based on sample after list wise deletions (N = 167). The six dimensions of beliefs and attitudes are scaled from *never* = 1 to *always* = 5.

Table 2 shows the descriptive statistics and descriptions of variables of the questionnaire. The mean scores of the affective domain of the students in the six dimensions are all above the value of 3, with attitudes towards mathematical modeling indicating the highest mean score of 4.09. This indicated that Brunei pre-university students have stimulated attitudes towards mathematical modeling and demonstrated positive attitudes towards learning of mathematics.

Table 3. Frequencies and percentage count of items rank.

Items (Refer to Table 1)	**Item rank and no. of respondents (%)**	
	1 (Never) and 2 (Almost Never)	**3 (Sometimes), 4 (Almost Always) and 5 (Always)**
1.	11 (6.59)	156 (93.4)
2.	15 (8.98)	152 (91.0)
3.	19 (11.4)	148 (88.6)
4.	1 (.60)	166 (99.4)
5.	11 (6.59)	156 (93.4)
6.	8 (4.79)	159 (95.2)
7.	6 (3.59)	161 (96.4)
8.	12 (7.19)	155 (92.8)
9.	2 (1.20)	165 (98.8)
10.	4 (2.40)	163 (97.6)
11.	31 ((18.6)	136 (81.4)
12.	14 (8.38)	153 (91.6)
13.	18 (10.8)	149 (89.2)
14.	14 (8.38)	153 (91.6)
15.	30 (18.0)	137 (82.0)
16.	13 (7.78)	154 (92.2)
17.	25 (15.0)	142 (85.0)
18.	66 (39.5)	101 (60.5)
19.	15 (8.98)	152 (91.0)
20.	88 (52.7)	79 (47.3)

Table 3 indicates that more than 90% of the sample was keen to take mathematics lessons and learn new ideas and theories in mathematics. These students have significant positive beliefs towards mathematics (see also Table 4) and they also equally think learning of mathematics through understanding of the theorems is as important as memorising formulae. This may be due to the fact that the syllabus emphasised computational accuracy and taught procedures, which consequently led to examinations focusing on students' abilities to use the learnt procedures. This added to students' progressive instrumentalist beliefs that mathematics is a subject that is focused on numerical computation without much interpretation of the solutions obtained. However, more than 90% of the sample thinks that mathematics is useful and is used in their everyday life routines with 99% of the students thinking that mathematics is useful in their future career (refer to Table 3). Our findings are consistent with Wilkins and Ma's (2003) study, in which high school students at Grade 12 developed less negative attitudes towards mathematics and less negative beliefs about the social importance of mathematics after being exposed to challenging mathematics curricula like calculus. Our analysis further revealed that affective competencies of Brunei students are stimulated and can be further developed into cognitive competencies by participating in structured modelling experiments and activities in a learning environment.

Table 4. Frequencies and percentage count of items rank based on the six dimensions of learners' views.

Six Dimensions of learners' views (factors)	**Item rank and number of respondents (%)**				
	1 (Never)	**2 (Almost Never)**	**3 (Sometimes)**	**4 (Almost Always)**	**5 (Always)**
1. Attitudes towards mathematical modeling.	4 (.60)	42 (6.29)	164 (24.6)	149 (22.3)	309 (46.3)
2. Positive beliefs.	10 (1.50)	27 (4.04)	261 (39.1)	210 (31.4)	160 (24.0)
3. Self-beliefs.	14 (2.10)	37 (5.54)	247 (37.0)	250 (37.4)	120 (18.0)
4. Attitudes towards social context.	16 (3.19)	46 (9.18)	260 (51.9)	127 (25.3)	52 (10.4)
5. Instrumentalist beliefs.	34 (6.79)	70 (14.0)	193 (38.5)	129 (25.7)	75 (15.0)
6. Use of technology in learning mathematics.	39 (11.7)	64 (19.2)	102 (30.5)	76 (22.8)	53 (15.9)

Table 5 shows the correlation scores of the affective domain of the students in the six dimensions. In general, the correlation scores are positive, significant, but not very strong. In particular attitudes towards mathematics modeling correlate positively to positive beliefs and attitudes towards social context. Mata *et al*. (2012) also reported significant results related to teacher support in the development of positive attitudes towards mathematics by stimulating intrinsic motivation in students. Some examples are shaping student expectations about learning in a positive way, setting meaningful but not excessively challenging task and promoting cooperative learning environments (Mata *et al.*, 2012). Biccard and Wessels (2011) reported on the significance of environmental factors particularly, social interactions that help form learners' beliefs about mathematics. Our study shows that the interaction of these beliefs and attitudes contributes to students, who seek help from tutors or peers and prefer to work in groups, exhibiting positive beliefs towards mathematics, and will have stimulated affective competency in mathematical modeling, which is part of learning mathematics.

Table 5. Correlations between variables

Variables	Attitudes towards mathematical modelling	Positive beliefs	Self-beliefs	Attitudes towards social context	Instrumentalist beliefs
Positive beliefs	.364**	-			
Self-beliefs	.257**	.564**	-		
Attitudes towards social context	.223**	.223**	.223**	-	
Instrumentalist beliefs	-.112	.015	-.002	.119	-
Use of Technology	.155	.332**	.257**	.189*	-.011

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

5. Conclusion

Many of the standard-based mathematics curricula in schools are heavily dedicated to the development of students' computational skills, and provide little opportunity for students to demonstrate the complex types of reasoning and interpretation skills that characterized a highly competent student. Therefore, the tests used and grades given in such programs usually reflect that structure, and exclude reasoning and interpretation abilities in mathematics. What this typical class environment practiced by most educators in Brunei needs is the integration of mathematical modeling to facilitate the learning of mathematics and to contribute to the development of various mathematical competencies (Blum, 2011). This is an association and satisfaction that is most needed by students to acquire meaningful and contextual learning between abstract mathematics and the real world, reversing the negative trends often related to beliefs and attitudes toward the learning and application of mathematics. This study marks the beginning of the possibility of integrating mathematical modeling into the Brunei school curriculum. The results of our study showed that Brunei pre-university students have stimulated beliefs in learning mathematics and positive attitudes towards mathematical modeling as part of learning mathematics. Thus, teachers should provide meaningful activities that encourage the development of cognitive and affective domains of students.

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