Structural equation modelling of affects and learning approach in mathematics education

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Abstract: As most students recognize that affect and context influence their learning methods, this is reflected in the theory of Student Approaches to Learning (Biggs, 1993). This paper investigates the relationship of preservice teachers' affective characteristics and student's learning approaches using structural equation modeling to examine the relative contributions of latent factors, and to find the strength of their impacts to mathematics achievement. Based on the presage-process-product model of student learning, a hypothesized model is proposed that preservice teachers' mathematics self-concept, mathematics teaching self-efficacy, beliefs and attitudes towards mathematics and mathematics education, influence cognitive activities in the learning process and subsequently mathematics achievement outcomes. It is found that mathematics teaching self-efficacy acts as the mediator of affective characteristics, learning approaches and mathematics achievement. The finding proves useful to educators in the research areas of affective domain of mathematics education. The paper ends with discussions and limitations for the study. It is hopeful that the proposed model will become a useful reference for further investigations on affective domain of mathematics education

INTRODUCTION

Beliefs, self-concept, attitudes and self-efficacy are all interrelated and are likely to affect academic achievement (Relich & Way, 1994; Philippou, 1998; Thompson, 1992). It is argued that in the area of mathematics education, these factors form a complex network that brings about changes in mathematics achievement. Therefore, the focus of this study is to clarify the directions and magnitude of the relationships between these variables among preservice teachers of primary mathematics. In doing so, a path model will be created to explain the relationships between factors affecting pre-service primary teachers' mathematics self-concept, mathematics self-efficacy, learning approaches, beliefs and attitudes toward mathematics education in Hong Kong.

Philippou (1998) suggested that positive teacher attitudes contribute to the formation of positive pupil attitudes. Haladyna, Shaughnessy and Shaughnessy (1983) provided support for this claim. Their findings showed that teacher quality, which included teachers' attitudes, was a causal factor for students' attitude towards mathematics. If their argument is accepted, then it is highly undesirable for those who have unfavourable feelings about mathematics to teach mathematics in school. Thus, it seems reasonable to assess the relationships of preservice teachers' beliefs, self-concept, attitudes and self-efficacy, with respect to mathematics and mathematics education which can serve as an indicator to evaluate the effectiveness of the programmes. Therefore, it is theoretically significant to find out the latent constructs influencing how the preservice primary teachers value mathematics and mathematics education, and to what extent the affective characteristics influence their learning approaches, and in turn, the effect on achievement in mathematics and mathematics education. In particular, the model proposed is able to explain the interrelationship of beliefs, attitudes, mathematics self-concept, mathematics self-efficacy, learning approaches and mathematics achievement. The strength of the factors and the relations within and between the factors of the affective characteristics can also be found through structural equation modeling. Moreover, as a clearer picture of how students learn and a better knowledge in the affective characteristics of the learners would no doubt help in improving the quality of student learning, the findings of the study may form the basis for future intervention programmes which aim at improving students' mathematics achievement.

DESIGN AND METHOD

Subject The subjects of the were 206 first year preservice teachers enrolled in the two-year full-time and three-year full-time Certificate in Education courses at Hong Kong Institute of Education. The students composed varied classes at the academic year 1999-2000.

Instruments

The instruments were a questionnaire composed of six parts. Part I was designed to collect personal background information such as age, gender and school experience. Part II measured the extent of preservice teachers' beliefs in mathematics and mathematics teaching, while Part III measured self-concept with respect to mathematics and attitude towards mathematics and mathematics teaching. Part IV measured preservice teachers' mathematics-teaching self-efficacy while Part V measured learning approaches. Finally, Part VI consisted of a series of questions requesting the participants' to identify factors influencing their feelings about mathematics and their confidence to teach mathematics. Parts I and VI of the questionnaire were not used in the SEM. These two parts are described in the following section. Parts II to V of the questionnaire were used in the SEM, along with the preservice teachers' grades for the mathematics course and for the mathematics-education course, to construct the model relating characteristics and achievements. They consisted of Likert scales covering the four different affective characteristics (mathematics and mathematics-teaching beliefs, mathematics self-concept, mathematics and mathematics-teaching attitudes, and mathematics-teaching self-efficacy) and the three different learning-approach characteristics (surface, deep and achieving). Each of these characteristics was measured by two scales. These fourteen formal scales were based on instruments that had been translated into Chinese and validated for Hong Kong tertiary students by other researchers. For the measurement of mathematics achievement, students' actual grades in *Introduction to Mathematics* (mathematics content course) and *Primary Mathematics Curriculum and Teaching (I)* (mathematics method course) were collected through two items in the questionnaire.

PROCEDURE

All data collected from the instruments described were at the end of the second semester of the 1999-2000 academic year at the Hong Kong Institute of Education. At the end of the second semester, a six-part questionnaire was administered to 206 first year students. Students were first asked to complete background information, the beliefs statements about mathematics and mathematics education. Then, scales of affects with respect to mathematics and mathematics teaching and learning approaches were completed. All instruments were administered at the end of class period. The questionnaire was handed out to preservice teachers during a mathematics class in first semester. The teachers were briefed on how to complete the questionnaire. Particular attention was given to confidentiality and to completing the questionnaire individually.

Analysis

The data from the questionnaire and the preservice teachers' grades were analyzed using the statistical software *SPSS for Windows and LISREL 8.30*. The data collected from the questionnaire were initially analysed for internal consistency reliability using SCALE from *SPSS for Windows*. Then ANOVA is used for investigating the gender and age difference between means for the affective characteristics. Moreover, for the analysis using Structural Equation Modeling (SEM), Parts II to V of the questionnaire and the grades were considered as eight latent variables. (1) mathematics and mathematics-teaching beliefs, (2) mathematics self-concept, (3) mathematics and mathematics-teaching attitudes (4) mathematics teaching self-efficacy, (5) surface learning approach, (6) deep learning approach, (7) achieving learning approach and (8) mathematics and mathematics-education achievements. Each of the eight latent variables was measured by two scales. Each of these scales and the mathematics and mathematics-education grades acted as observed *indicator* variables in the analysis. SEM examines both correlational and causal relationships among variables. Although the latent variables are not directly observed, they have operational implications for the relationships among observed variables. Hence, observed indicators and latent variables can be linked up by SEM, and therefore, a model can be formulated in the study.

RESULTS

Part I of the questionnaire from the survey indicates that there are 142 female and 59 male of the age ranging from 18 to 25 years old have completed the questionnaire. Overall, the majority of the pre-service primary teachers under the pilot study were found to have reasonably favourable feelings about mathematics and mathematics education. With respect to the open-ended questions in Part VI of the questionnaire, in which preservice teachers were asked to describe factors influencing their feelings about mathematics and their confidence about mathematics teaching, students tended to describe feelings rather than providing factors. Many students expressed positive statements such as "mathematics problems are interesting and challenging", "I do enjoy teaching mathematics", "I am quite good at mathematics". However, others expressed negative feelings. For example, some preservice teachers said that they never did well on tests that require mathematical reasoning, some hesitated to take courses involving mathematics, and others were not sure about what to do when teaching mathematics.

For Part II to V of the questionnaire, the preservice teachers' responses were positive with respect to beliefs and attitudes towards about mathematics and mathematics teaching. The responses were also positive with respect to mathematics-teaching self-efficacy but less positive with respect to mathematics self-concepts. The responses indicated that preservice teachers' learning approach was predominantly surface learning.

The coefficient alpha that measures the internal consistency reliability estimates for the overall instrument is .8449. According to Nunnally (1978), these coefficient alphas are within the acceptable range for research purposes in social science. They are comparable to those reported by Biggs (1992) for the Study Process Questionnaire samples in Hong Kong.

Gender and age difference

As shown in Table 1, the gender difference between the means for personal mathematics teaching self-efficacy were found to be statistically significant: $F(1, 199)=8.747$, $p<.05$. Similarly, the gender difference between the means for belief about mathematics were found to be statistically significant: $F(1, 198)=6.709$, $p<.05$. The gender difference between the means for self-concept about mathematics were found to be statistically significant: $F(1, 198)=7.715$, $p<.05$. Finally, The gender difference between the means for attitude about mathematics teaching were found to be statistically significant: $F(1, 198)=4.478$, $p<.05$. It is interesting to find that there is no significant gender difference in mathematics achievement.

Table 1: *Gender difference in affective characteristics*

Observed variable	Sum of Squares	df	Mean Square	F	Sig.
Personal mathematics teaching self-efficacy	Between group 88.603 Within group 2015.79	1 199	88.603 10.130	8.747	.003
Belief about mathematics	Between group 59.122 Within group 1744.86	1 198	59.122 8.812	6.709	.010
Self-concept about mathematics	Between group 331.441 Within group 8505.714	1 198	331.441 42.958	7.715	.006
Attitude about mathematics teaching	Between group 226.369 Within group 10008.98	1 198	226.368 50.550	4.478	.036

However, there significant difference among age groups for mathematics teaching outcome expectancy ($F=2.092$, $p<.05$), achieving motive ($F=3.36$, $p<.05$), self-concept about mathematics ($F=2.778$, $p<.05$), attitude towards mathematics teaching ($F=2.863$, $p<.05$) and mathematics education achievement ($F=3.275$, $p<.05$). The details are shown in Table 2 as below.

Table 2: *Age difference in affective characteristics*

Observed variable	Sum of Squares	df	Mean Square	F	Sig.
Mathematics teaching outcome expectancy	Between group 179.207 Within group 2372.570	7 194	25.601 12.235	2.092	.046
Achieving motive	Between group 492.884 Within group 4024.111	7 192	70.412 20.959	3.36	.002

Self-concept about mathematics	Between group 283.836 Within group 2802.759	7 192	40.548 14.598	2.778	.009
Attitude about mathematics teaching	Between group 170.916 Within group 1646.079	7 193	24.417 8.529	2.863	.007
Mathematics method course	Between group 12.695 Within group 107.995	7 195	1.814 .554	3.275	.003

The final path model of affective characteristics

Based on the correlations among variables, SEM produced path models with different parameters. Figure 1 shows the final path model with best fitting path coefficients for the latent constructs in the study. The arrows with the path coefficients indicated the direction and magnitude of the relationships between the variables. Although the magnitude that indicated the strengths of the relationships were not high, they were all significant. Paths with coefficients not significant at .05 level were deleted from the model and therefore the process variable of "Achieving Approach" was deleted from the model.

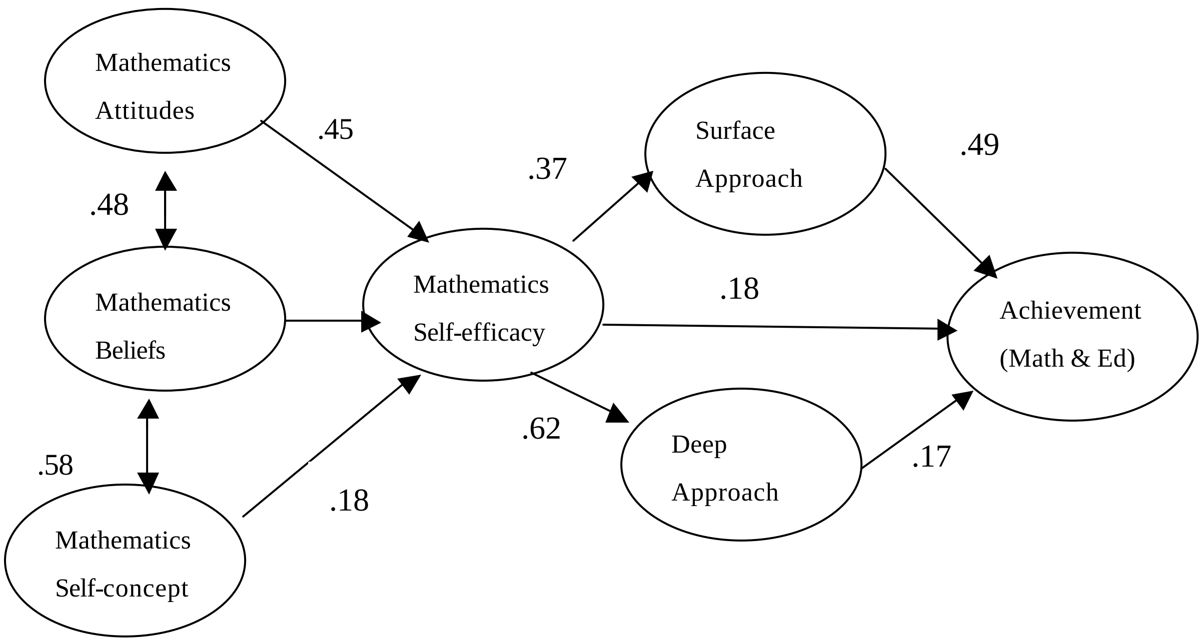

Figure 1. The final model of relationships among theoretic affective characteristic

Goodness of fit statistics

Maximum likelihood estimation was employed to estimate all models. The independence model that tests that hypothesis that all variables are uncorrelated was easily rejected since the Chi-square value is too large (Chi-square statistics =718.25, p<.001). The Chi-square test of fit and other goodness of fit indices also reject the initial model. For the detail of goodness of fit statistics, the fit statistics indices are given in the Table 3 for the initial as well as final model. The Chi-square test of fit of badness cannot solely determine whether or not accept the final model. However, following the guidelines of Browne and Cudeck (1993), the point estimate of RMSEA is below .05 that lead to the conclusion of accepting the model. Another indication that the model fits well is that the ECVI for the final model (.508) is less than the ECVI for the saturated model. In fact, the goodness of fit index for the final model is .92 and therefore, the model fits well and represents a reasonably close approximation in the population. By SEM procedures, the goodness of fit index of the final model described below is generally accepted as the evidence of a good fit for the sample size of 200 (Kelloway, 1998).

Table 3: *Goodness of fit index*

Types of goodness of fit index	**Goodness of fit statistics for initial theoretic model**	**Goodness of fit statistics for the final model**
Chi-square with 94 degrees of freedom	525.81	498.28
Root mean square error of approximation (RMSEA)	.15	.048
Expected cross-validation index (ECVI)	.51	.508
Goodness of fit index (GFI)	.78	.92
Adjusted goodness of fit index (AGFI)	.66	.90
Parsimony goodness of fit index (PGFI)	.53	.49
Normed fit index (NFI)	.64	.91
Parsimony normed fit index (PNFI)	.50	.62
Comparative fit index (CFI)	.68	.95
Relative fit index (RFI)	.54	.89
Incremental fit index (IFI)	.69	.94

DISCUSSION

The result of this study concludes that there is statistically significant gender difference between the means for personal mathematics teaching self-efficacy, mathematics self-concept, belief and attitude. There is also statistically significant age difference among age of preservice teacher for mathematics teaching outcome expectancy, mathematics self-concept and grade of mathematics method course. It appears that the older preservice teachers tend to know the need of methods of teaching mathematics and male preservice teachers seem to have higher and positive self-concept, belief and attitude toward mathematics.

With the significant path coefficients, the results also support the view that mathematics belief, attitude, and self-concept affect mathematics teaching self-efficacy that acts as a mediator, affect learning approaches and subsequently influence mathematics achievement. In this study, factor analysis also supported a two-factor solution with the surface and deep approaches. It is observed that mathematics teaching self-efficacy has a negative effect on the surface approach to learning. It can be argued that a student who has mathematics teaching self-efficacy will also has confidence of his ability of teaching, and therefore, takes up personal responsibility for his own learning. As a result he will seem to be less likely to resort to superficial learning strategies. The result obtained in this study is consistent with the findings of other researchers such as Drew and Watkins (1998) who conducted a similar study of relationships among self-concept and learning approaches in Hong Kong.

IMPLICATION

The proposed model in this study will become a useful reference for further investigations on affective domain of mathematics education in primary school. It also has implication for policy-making: it help policy makers to set up appropriate selection criteria for admission to the course in long term and to revise the curriculum of courses of mathematics at Hong Kong Institute of Education, so as to improve the quality of learning and teaching mathematics for the preservice primary teachers in Hong Kong. Research has indicated that beliefs about mathematics were influenced by earlier school experiences, beliefs about teaching mathematics were influenced by teaching practice, and the teacher preparation programs (Jones & Vesilind, 1996; Raymond, 1997). However, very little researches have been done locally on preservice teachers' beliefs, self-concept, attitudes and self-efficacy with respective to mathematics and mathematics education. Hence, this study attempts to fill a gap in mathematics education research in Hong Kong.

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