TRANSITION FROM SENIOR SECONDARY TO UNIVERSITY MATHEMATICS: A CASE STUDY

YACHAI PONGBORIBOON
Faculty of Education
Khon Kaen University, Thailand

INTRODUCTION

In Thai secondary school mathematics occupies a central place in the curriculum, and this reflects the vital role the subject is seen to have in the task of preparing more productive citizens. There is a common belief that mathematics is the exemplar of precise, abstract and elegant thought. Indeed, there appears to be an almost universal consensus that the study of mathematics helps to broaden and hone intellectual abilities (Travers and Westbury, 1987). From a societal perspective, mathematical competence is seen as the cornerstone of a numerate society, and that therefore the industrial, technological, and scientific future of a nation depends on more children going on to study higher mathematics than ever before.

The need to establish equitable criteria for the selection of students for entry to mathematics and science programs in Thai universities is the major background issue influencing the direction of this present study. Why do so many school graduates find the entrance examination test difficult? (Makpoon, 1989; Patitas, 1989; Premto, 1987) And why have from 30 to 60 percent of first-year students at Khon Kean University always failed examinations in mathematics courses? (Khon Kaen University, Faculty of Science, 1989). One possible explanation is that students admitted to the scientific and technological courses at Khon Kaen University experience difficulty in the first-year mathematics courses because they are not well prepared in the secondary schools for these courses (see Pongboriboon, Somsoporn, and Krewawarn, 1989).

Morgan, (1989) after analysing the results of national and international surveys, concluded that there is a common message that mathematics appears to be a difficult subject to teach and to learn and that there is great concern about the overall level of mathematical competence. Also there is a concern that a large proportion of the students who enter university come poorly trained in mathematics.

Clearly, there are a number of factors that play important roles in mathematical learning. A study by Lorenz (1982) found that ability is the most important factor determining mathematics achievement, with the second most important factor being motivation. The attainability of higher education is also affected by the way in which individual attributes act in combination with characteristics of a young person's situation. The performance of Thai students in mathematics should relate to their academic environment, ability background, study habits, and the teaching competence of their mathematics teachers.

This paper addresses the question of why so many first-year students at Khon Kean University (hereafter referred to as KKU) experience difficulties in coping with their mathematics courses. Factors apparently directly related to difficulties associated with students' transition from senior secondary school to university mathematics are a special focus of the study. Also, the varying extents to which school teachers, university lecturers, and first-year students differ in their perceptions of how school and university mathematics courses should be related are studied.

PROCEDURE

In order that a deeper understanding of the importance of variables affecting performance on first-year mathematics courses at KKU might be obtained, an investigation involving the collection and analysis of both quantitative and qualitative data was carried out. The investigation focussed especially on the difficulties experienced by first-year mathematics students at KKU.

THE SAMPLE

A small group of senior secondary school mathematics teachers, university mathematics lecturers, and first-year mathematics students from six faculties at KKU were interviewed during the first semester of 1990. This group consisted of:

1. twelve school mathematics teachers located in twelve schools - six in the Khon Kaen city area and six in rural areas.

2 ten mathematics lecturers who taught first-year mathematics courses in the first semester, 1990, at KKU; and

3. twenty-four first-year KKU mathematics students, comprising four students from each of six faculties (Medicine, Nursing, Agriculture, Engineering, Science, and Education). The students from each faculty were selected by using mid-term mathematics examination performance as the criterion, one student having high achievement, two average achievement, and the fourth, low achievement

RESEARCH INSTRUMENTS

Measures of the mathematics achievement of students beginning mathematics studies in six faculties were obtained by using a school mathematics achievement (SMA) test. This pencil-and-paper, multiple-choice instrument was constructed by the present writer with the assistance of a group of experienced senior secondary school mathematics teachers. It was intended that scores on the SMA test would not only reflect individuals' understanding of senior secondary mathematics, but also how well schools had enabled students to acquire the basic skills needed for effective mathematical study in tertiary institutions.

Other information on the extent of the mathematics known by beginning first-year KKU students was provided by students' scores on one of the standard entrance examinations in mathematics, namely the Direct Entrance Examination Mathematics (DEEM) test, administered by KKU, and National Entrance Examination Mathematics (NEEM) test, administered by the Thai Ministry of University Affairs.

In order that a deeper understanding of the difficulties in mathematics experienced by first-year KKU students might be arrived at, interviews with senior secondary mathematics teachers, and first-year KKU mathematics students and lecturers were conducted by the author during the first semester of 1990. These interviews were based on a structured questionnaire schedule, the aim being to identify causes of student difficulties in first-year mathematics. In the interviews special attention was given to identifying difficulties that might be directly associated with the transition from senior high school to university mathematical study.

DATA ANALYSIS

The students' mathematical abilities at the beginning of their university study were measured by scores obtained on the SMA (N=946), DEEM (N=451), and NEEM (N=471) tests. These scores were analysed using standard techniques in which mean scores and standard deviations became the basis for comparison. The Mathematical performances of student taking first-year programs in six different faculties at KKU, together with interview data, were used for the purpose of examining the students' mathematics abilities and their willingness and preparation for university mathematical study.. The interview data were analysed and classified into two main areas: (a) those which threw light on the source of students' difficulties; and (b) the views held by the school teachers, the students, and the KKU lecturers on relationships between school and university mathematics, and on other issues that might be expected to influence performance on, and attitude towards, first-year mathematics at KKU.

RESULTS

Analysis of the quantitative and qualitative data indicated that there were six major influences affecting the first-year KKU mathematics performance. These major influences were:

1. the students' mathematical abilities at the beginning of the University year;
2. curriculum content;
3. course organisation;
4. the students' study habits;
5. instructional styles; and
6. assessment procedures.

The influence of each of these factors will now be summarised.

THE STUDENTS' MATHEMATICAL ABILITIES AT THE BEGINNING OF THE UNIVERSITY YEAR

A number of selected test items from the DEEM, NEEM and SMA instruments were given to the interview sample to consider from the point of view of test validity. Approximately one-fourth of the items on each instrument (12 from 50 on DEEM, 10 from 48 on NEEM. and 10 and 7 from 30 items on the SMA test) were chosen for this purpose, the criterion for item selection being the set of items chosen should cover the major themes in senior secondary mathematics in Thailand.

The interviewees reported that the test items had content validity, that is to say the three instruments were strongly related to the mathematical content and skills emphasised in senior secondary schools in Thailand. Also, according to the interviewees, most of the selected test items were of suitable difficulty, although a few of the items on the entrance examination tests (DEEM and NEEM) were deemed to be quite complex.

The mean DEEM and NEEM scores obtained by the students in the main sample were 43.8 and 32.2 respectively (with a maximum possible score of 100 for each examination), and 13.3 for the SMA test (with a maximum possible score of 30). Since it appeared to be the case that the three instruments had strong content validity, so far as senior secondary mathematics was concerned, and few if any of the items were regarded by teachers as unreasonably difficult, these results can hardly be regarded as satisfactory. Indeed, it could fairly be concluded that many students in the sample lacked the basic mathematical skills and knowledge needed to cope with first-year mathematics courses at KKU.

At the examinations taken at the end of the first KKU semester in 1990, 27.2% of the first-year university mathematics students in the main sample for this study obtained an F grade, and 32.4% obtained a D grade (F was the lowest possible grade and is regarded as a "Fail"; and D was the second lowest grade, and was regarded as a borderline Pass). Therefore, there is strong evidence that at the first semester examinations in 1990, more than half of the students in the main sample failed to demonstrate a sound understanding of the mathematics that they had studied during the semester.

The data finding suggested that most of the students in the main sample were not well prepared, from the point of view of having necessary and desirable mathematical knowledge and skills, to take first-year mathematics courses at KKU. Consequently, many of the students were unable to cope with first-year mathematics courses at KKU, and they did not perform well on the first semester mathematics examinations In other words, students who are not well mathematically well prepared for first-year mathematics courses will not gain much benefit by taking the courses - mere participation in the course did not seem to remedy their mathematical weaknesses or improve their mathematics competence.

Results from the interviews with the school mathematics teachers, the university mathematics lecturers, and the mathematics students revealed further insights into the difficulties students experienced in coping with first-year university mathematics. In particular, these brought out the relationships conceived by each group between the school and university levels in terms of the curriculum content, the course organisation, and the study habits acquired by students in school and university settings.

CURRICULUM CONTENT

There was agreement from all groups interviewed that the mathematics curriculum for senior high school covered most of the content areas which are necessary for further mathematics at the higher education level. However, some content, such as *vectors* and *calculus*, was felt to be in need of clearer explanation in the mathematics textbooks provided for the school curriculum. Limitations on the time available for instruction also meant that it was difficult to cope sufficiently with crucial concepts related to these topics. The teachers also reported that students frequently manipulated the mathematics in a superficial way rather than gain a depth of understanding of the content, and that this is a possible cause of some of the difficulties experienced by students at the university.

There were, however, two topics which are not taught at each of the school and university levels. *Groups*, a part of the mathematical content in Year 10 does not directly relate to any content in the first-year university mathematical course, while *Mathematical induction* which is a component of 314 111 Mathematics 1 for Science and Education faculty students was not considered at the school level. In addition, it was felt that the school mathematics textbooks provided very simple explanations and straightforward approaches to the content in such a way that these probably contributed to the development of conceptual blockages in students. Consequently, most students discovered that the mathematics syllabus at the university level was pitched at a level that appeared to be unreasonable in terms of their knowledge and experience and far higher conceptually than they were able to accommodate.

In summary, the interview data revealed that there was a reasonable degree of articulation between the mathematics curricula at the school and the university at the topic level. However, a lack of precise details and complete explanations provided insufficient depth of understanding of basic concepts, knowledge and skills sufficient for the *conceptual preparation* required for university study in mathematics. Further, at the university, lectures were based on the assumption that the school graduates were familiar with all the knowledge and skills provided in the school mathematics curriculum. Yet the test data revealed that, generally, this was far from the case. Discrepancies between the two curricula at senior secondary school and first-year university in terms of content and conceptual understanding were a further source of difficulties for students trying to cope with their first-year mathematics courses.

COURSE ORGANISATION

Class sizes were felt to be too large at both the school level, with 45 to 50 students per class, and in university lectures with 135 to 225 students. There were also commonly reported difficulties caused by the text material from which the mathematics was to be learned, although the Thai mathematics textbooks used in all high schools are published by the Ministry of Education. Teachers reported difficulties in comprehending the meaning due to inconsistencies in the use of the bold and italics words used to highlight important points and the unsystematic use of punctuation. For instance, the same number of spaces was used between clauses or sentences. As the Thai language does not have commas or full stops, but uses spaces to indicate punctuation, writing mathematics in Thai language requires particular care to avoid ambiguities and misunderstandings. Misprinted words were also found in both theorems and exercises.

At the University level, most students indicated that the structure of the written language in the course material produced by the Department of Mathematics was very difficult to comprehend without also attending the lecture classes. The only examples involved given procedures and the use of rules or concepts, rather than the concepts themselves, and some of the examples were not clear. In addition the students felt that examples could not be generalized to provide solutions for most of the exercises, so that they were unable to do many of the exercises. Some lecturers pointed out that reading the mathematics texts assumed a mental or cognitive structure in the students' mind corresponding to the mathematical context to be learned. They justified this by arguing that learning from texts in which all aspects were immediately recognizable by the students would prevent the students from learning to handle texts independently.

Tutorial programs were also provided by the Department of Mathematics during worktime and by the University after office time in the late afternoon and during weekends. However, it appeared that only a small number of students,15-35 percent, attended tutorials regularly. The students claimed that many did not attend because they expected to be asked questions which, if they had not prepared themselves by studying the previous mathematics lessons or by completing the exercises, they would be unable to answer. A particularly strong reason for non-attendance was that many students reported that they felt too tired after attending five-seven hours per day of normal classes. The university tutorial program which was intended to remedy students' mathematical deficiencies failed because it did not involve those who required assistance. The difficulties in attending were, in fact, generally made even harder because first-year students were recommended to register for seven-nine courses during each semester, requiring attendance at classes for about 19-24 hours per week.

THE STUDENTS' STUDY HABITS

Teachers reported that the senior secondary school students developed undesirable study habits at school mathematics classes. In particular, the students' concentration during mathematics classes was inconsistent. If the topic was understandable they would pay attention and try to do exercises by themselves, but if the topic was too difficult for them, their attention would be lost and they would give their attention to other matters. Most students also completed their homework exercises by simply copying the work of friends or from a mathematics guide. The students indicated that mathematics teachers directly taught every detail of the mathematical processes and that they practised mathematics exercises by simply following these steps. Consequently, they could not solve other mathematical problems which required different approaches.

Differences in the demands of mathematics courses between the school and university required students' to adjust their study habits, but they experienced difficulties in seeing the need for and achieving these changes. Lecturers and students felt that mathematics deficiencies of first-year university level resulted from:

1. Differences in students' study activities between high school and university level:
   - (a) acting skills and dispositions necessary for autonomous study; and
   - (b) a shift from superficial study to productive study practices

2 Undesirable study habits developed in university study level:
   - (a) do not attend class and tutorial consistently;
   - (b) allocate insufficient time to study and review content; and
   - (c) do not enough practice on mathematics exercises.

INSTRUCTIONAL STYLES

Instructors at both school and university levels typically taught the whole class as a unit using a teacher-centred approach. The mathematics school teachers planned carefully for mathematical lessons, strictly following mathematics class textbooks to teach conceptual and procedural knowledge. The feedback on students' submitted school assignments focussed on correct or incorrect answers, but did not give adequate attention to any missing mathematical problem solving steps. The lecturers used the interrogative format as the instructional mode of choice during all phases of lessons, but did not expect and indeed moved on without receiving students' responses.

The first-year KKU students reported that the style of teaching mathematics at university was similar to the style they had experienced at high school level, that is, a content-focused lecture approach. At university, little or no class time was given to reviewing prerequisite mathematical concepts. University lecturers expected students to understand the mathematical topics which were listed in the senior high school syllabus. University lecturers would not review or clarify such concepts to provide a link to the new knowledge. The pace of university lecturing was very fast. Many students lost the factual ideas if they tried to interpret what was being said and integrate the new knowledge into their experience. In a mathematics lecture class, the students claimed that they were unable both to listen and to take notes, most settling for one or the other.

ASSESSMENT PROCEDURES

Each secondary school sets its own examinations, tests and assignments. The Ministry insists that the ninety percent of the total assessment come from mathematical achievement performance as indicated by testing and examination (three examination during the semester and the final examination), leaving ten percent of the total assessment for the teacher's perception of students' value to the subject. Most of the teachers used objective test styles, particularly multiple-choice test format, for the three examinations during and the examination at the end of the semester. In practice, for the remaining assessment, the school teachers used their scoring of work submitted by students instead of giving their perception of the ways students value the subject of mathematics, mostly awarding all students close to ten percent.

Students claimed that their school mathematics experience of looking for a correct answer in a multiple-choice item question, did not prepare them for the university requirement of demonstrating mathematics processes in a written test where all working had to be shown. In KKU mathematics courses, achievement was assessed by summing scores of two only performances: 40 percent from a mid-semester test and 60 percent from the final examination; no account was taken of performance on class exercises or assignments.

DISCUSSION

The students at the upper secondary school level learned details of mathematical knowledge, but could not comprehend and generalize to operational procedures. This finding confirmed some difficulties reported in the literature concerning the teaching of mathematics. Teaching materials and aids are needed to build concepts and abstract mathematics content.

In addition, it revealed a need to change the classroom situation from teacher-centred to student-centred so as to focus students' interest on the lessons.

Examining the perceptions of the first-year mathematics students, and the university mathematics lecturers on the instructional styles at university mathematics classes, it was felt that the traditional lecture, content-focused approach seemed to be appropriate for a large class of more than one hundred students. However, while the content-focused approach was considered appropriate to develop students' factual knowledge, it only brought about superficial understanding (Marty, 1988). The teaching style at the university could not improve students' proficiency in mathematics. The first-year mathematics students who carried their mathematical deficiency from schools needed remedial courses before entrance into university or before studying a university mathematics course.

In addition, the students asserted that their aim in studying mathematics at high school was to pass the school examinations and then more specifically to pass the university entry examinations, both of which were composed of multiple-choice items tests. Accordingly, the students learned to develop their operational skills directed to finding a path straight to the correct answers. They considered themselves as lacking deep understanding in many mathematics concepts, and lacking skills of mathematical operational processes. These mathematics deficiencies from the students' view were the results of their lack of practice in the mathematical operation and the results of schools using inappropriate evaluation tools.

Some suggestions on senior secondary mathematics course were made by both school teachers and students. They agreed on the following suggestions for reform in the secondary school mathematics curriculum:

1. Some curriculum topics should be reviewed. Content areas should be given more detailed explanation, and a range of examples giving applications of the theorems in some of these topics, such as *vectors*, and *calculus*. Overlapping of mathematics content among different years of study should be examined and remedied, for an example, *exponential function and logarithmic functions* in Year 11 and *exponents or indices* in Year 9.

2. Some topic contents should be rearranged:

   (a) In Year 10 mathematics curriculum, the topics are ordering from lines, functions, and conics should be changed to *lines, conics,* and *functions,* because the content in conics is rather related to lines and it should be taught continuously;

   (b) In Year 11 mathematics curriculum, it was suggested that the content in *complex number* should be reduced. Then the topic of *calculus* which needed to be taught more precisely could be moved from chapter 3 to replace chapter 1; and

   (c) All of the topics related to *elementary statistics* were taught in the second semester of Year 12. It was suggested that, instead, the content be grouped into a few main topics and then put separately into other mathematics year levels. In turn, this content could be replaced with other topics from the mathematics curriculum of Year 10 and Year 11.

Suggestions were also made for the first-year mathematics curriculum. In each content area, more exercises should be given and some of these should relate to every-day-life mathematical problem solving. However, the mathematics problems set in the examinations were much more difficult because they were not directly related to the type of exercise provided for practice. More difficult mathematical problems are also needed in the exercises provided in the text to assist students to move towards the expectations of the examinations.

In conclusion, the present author believed that this study makes three contributions. First, mathematics curricula in both senior secondary school and first-year levels should be reviewed and some rearrangement of topics carried out. Second, University mathematicians must play an active role in precollege education. Some articulation programs with co-operative partnerships between KKU mathematics department and high school mathematics teachers should be designed to improve school mathematics curriculum and instruction. The first-year mathematics student needs to be prepared for autonomous study in lecture note-taking, mathematics reading skills, and awareness of self- directed study at the university level. Third, the assessment criteria and procedures affect students' beliefs and they orient their study habits to meet the particular forms of assessment. At the school level, the teachers should not only give their students practice in solving mathematical problems in the form of exercises or homework, but also items where full working is expected, rather than solely a multiple-choice format, should be set for the examinations. At the university mathematical level, lecturers need to be aware that assessing an individual's achievement needs to be based on more than examinations and should include different learning experiences. Course assignments in individual or small group work will lead students to be more involved in reading, studying, and practising mathematics. Appropriate criteria for assessing mathematical achievement and performance should derive partly from examinations and partly from their own practice with mathematical activities.

The findings of this study also relate to the policies at KKU. The Department of Mathematics lacks sufficient academic staff to service mathematics as a required subject for all faculties of study in the science program. Lecturing or tutoring in mathematics in smaller class sizes produces more effective teaching and learning outcomes. Finally, given the students' reported workload of seven to nine courses a semester in first-year KKU, it is clear that a school graduate who comes to the different academic environment and harder conditions of the university, is almost certain to experience difficulties. The required number of courses expected of first-year students should be reconsidered by the faculty to allow a more reasonable workload. Failure in first year courses not only causes difficulties for a beginning student, it carries further penalties in succeeding years when these courses have to be made up and added to the load for subsequent years.

This study has revealed the situations and causes of difficulties in studying mathematics experienced by first-year mathematics students at the university. If some of the suggestions derived from the study could be implemented at KKU and/or at institutes which are responsible for senior secondary schools, this should alleviate some difficulties experienced in their first-year of university mathematics.

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