TEACHING & LEARNING
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The transition from secondary to tertiary mathematics education

Introduction

In recent years there has been a growing interest in the transition from school to university. Reports identify problems in transition as a significant factor in learning mathematics, with international concerns about decreasing numbers of students opting to study mathematics at university and their decreasing levels of competence (Smith, 2004). In addition, serious concern has been expressed around a lack of essential technical facility, a marked decline in analytical powers, and a changed perception of what mathematics is, especially with regard to the place of precision and proof. Although there have been some studies on possible causes of transition problems, the amount of research in mathematics education at the tertiary level is still modest (Selden & Selden, 2001), and usually does not cover the secondary-tertiary transition well.

This 2-year study considered the evidence from New Zealand of the existence of a gap in the transition from school to tertiary study in mathematics and what factors might be promoting it. The aim was to identify the nature of any transition difficulties and analyse possible reasons for them. We found that there is a need for much better communication between teachers and tertiary lecturers and their institutions. Also while students are affected differently by the transition, their motivation for studying mathematics changed, and their confidence fell during the transition. It seems that improving study skills, and assisting them to acquire a facility for independent learning would help.

Aims and objectives

The overall aims of the project were:

- To investigate whether there are any key differences between secondary and tertiary approaches to teaching mathematics in New Zealand and if so, to provide evidence of the nature of those differences.
- To identify and analyse the reasons for any differences and explore ways to enrich mathematics teaching and learning by employing ideas from both schoolteachers and tertiary lecturers.
- To establish an ongoing dialogue, partnership and collaboration between the two sectors on the issue of the transition from school to tertiary mathematics.

The main objectives of the research were:

- To identify any key differences in the approach to education in mathematics between secondary and tertiary levels.
- To examine the influence of a number of key factors in the transition period from secondary to tertiary education in mathematics in order to identify key differences. These variables were: assessment; teaching style/emphasis; mathematical knowledge for teaching; teaching materials; technology; teachers' experiences; students' experiences.
- To identify any equity, social and cultural issues that might contribute to differences of approach between secondary and tertiary education in mathematics for particular groups.
- To develop a set of recommendations that might make the transition period from school to tertiary mathematics smoother and more beneficial for students and educators.
- To initiate a process for ongoing dialogue between school and tertiary mathematics educators and to facilitate the dialogue.
- To disseminate the research findings for the benefit of teachers and lecturers.

Research design and methodology

This research project involved a partnership between the principal investigators, Associate Professors Mike Thomas of The University of Auckland, and Sergiy Klymchuk of AUT University and other members of the research team, including both school and tertiary teachers. Thus the team was well balanced and comprised a group of individuals with very strong educational credentials, each of whom contributed to the design of the study as well as its implementation, analysis and writing.

This research employed a survey and case study methodology. The whole population of New Zealand calculus schoolteachers and tertiary lecturers was surveyed, using questionnaires. In addition those who agreed were interviewed and there was also some observation of school lessons and tertiary lectures. We also surveyed and interviewed a focus group of students, some still at school taking a first year university paper involving calculus, and others in first year tertiary. We felt that the thoughts and experiences of these groups of students would be particularly useful in forming an opinion on any transition difficulties.

Parallel questionnaires were sent to teachers of calculus in Years 12 or 13 in all 350 secondary schools in New Zealand and to all lecturers who teach calculus in the 31 Tertiary Institutions (Polytechnics, Universities, Wānanga and Institutes of Technology). The questionnaires were posted, complete with a stamped addressed return envelope. In addition, a follow-up copy was sent by email to remind the teachers and lecturers to reply. We received a total of 178 teacher and 26 lecturer responses. There are no figures available on the total number of calculus teachers in New Zealand schools, but we estimate the response rate at about 30 per cent of each population. In addition we also surveyed 77 students, 35 of whom were at school and taking a university course, and 42 who were in their first year of tertiary studies. Each participant was given the option of being interviewed. Those agreeing filled in their contact details at the end of the questionnaire enabling six lecturers, 16 teachers and 11 students to be interviewed. Those teachers and lecturers who were interviewed were then asked if they would be willing to have their teaching observed, resulting in observation of two lectures (two lecturers) and five lessons (four teachers).

Summary of findings

The conclusions arising from this research project are summarised below.

- There is a lack of knowledge and awareness by secondary teachers and tertiary lecturers of what is happening in the other sector's courses. This shows a need for closer communication between teachers and tertiary lecturers and their institutions, to include understanding of the unique nature of teaching and learning in each sector.
- There is a misalignment of the curricula of schools and tertiary institutions in some areas and this is causing some transition problems. Examples include the omission of work on sequences and series and vectors and matrices from NCEA. There is some evidence, although numbers were fairly small, that those students who studied the Cambridge A level examinations found the transition easier than those who studied NCEA (n=62, mean_{Cam}=2.38, $\text{mean}_{\text{NCEA}}$=3.11, t=2.10, p<0.05; difficulty 1–5, 5 most difficult) possibly due to the closer alignment of the content with university mathematics.
- Not all students are affected in the same way by the transition from school to tertiary study. Some take it in their stride and others, even among good students, have some serious difficulties. Reasons for problems

in transition mentioned by students included: the low level of lecturer–student interaction at tertiary level; the increased pace of the work; the higher workload; the changed teaching style; and the larger class size. To a lesser extent there were problems with understanding the language used in teaching.

- Teachers and lecturers are more likely to think that calculus is of benefit to society than students do, and are also happier with the amount of calculus in their course than students are. Students have reservations about the study of calculus that do not align with their personal life ambitions.
- There was a clear change in the factors motivating the 35 focus group students to study mathematics as they moved from school to tertiary study. At school intrinsic factors such as enjoyment, interest, ability, and the challenge dominate, but this changed to extrinsic factors, particularly the perceived value of mathematical study for future tertiary courses, for career and employment opportunities and for financial gain.
- In general, students' confidence in their ability to do mathematics falls between school and tertiary level.
- There may be a culture in NCEA of students aiming to achieve in mathematics standards rather than trying to gain the deeper understanding of Merit or Excellence. This leads to a tendency for teachers to teach to achieved level, including only what is necessary for this. This causes problems in the transition since tertiary work requires deeper thinking.
- Many students lack independent learning skills. A number of students thought that with an increased workload, and the demands of greater rigour they could have been better prepared if they had improved study skills, and particularly the ability for independent learning.
- Collaborative learning does not appear to be commonly encouraged in schools or tertiary institutions, with few formal arrangements outside of class time in place.
- Students lack key knowledge about the role of mathematics (especially pure mathematics) in learning, careers and in society, but say they would study more mathematics if they did. They need more information about applications of mathematics to real-life situations and its use in other disciplines as well as clearer information about the role of mathematics in society, career pathways, opportunities it can present, and other benefits of choosing to study mathematics.
- There is some disjunction in teaching emphasis and style between schools and tertiary institutions. Examples include a greater emphasis on applications and modelling, practice of examples (e.g., textbook questions), communication skills, teacher-student discussion, collaborative work and factual knowledge in school, while tertiary institutions value conceptual thinking, rigour and problem solving. In turn, students found the tertiary courses deeper and more challenging.
- The teachers in the study raised concerns about time constraints and workload, particularly their administrative workload. It was agreed that lecturers have more time to prepare their teaching and also more time to work together at departmental level. However, in spite of this, there was markedly less communication among the lecturers and less sharing of resources, although many said they received peer support if they faced teaching issues.
- Around three-quarters of the teachers and over 80 per cent of lecturers had not taken advantage of any professional development (PD) in the past two years. Yet around 28 per cent of teachers said their content knowledge was sometimes lacking or stretched and 25 per cent expressed the need for more calculus PD.
- Some school mathematics departments are at a considerable disadvantage in preparing their students for the transition due to their relatively low budgets, which severely hamper PD programmes, provision of technology and other pedagogical initiatives.
- Lecturers have greater flexibility than teachers in choice of assessment. Teachers expressed concerns about the importance of assessment, teaching to the assessment, and the overload of internal assessment. Students reported that they found the assessment at tertiary level much better and more efficient than at school. Some teachers failed to pay attention to important details associated with increased rigour in assessment questions.
- Teachers and lecturers seem to be using similar technology, although there is a perception among teachers that technology is used more at tertiary level than in secondary. It appears that technology use at both levels is somewhat ad hoc, lacking clear coordination and direction.
- The change in technology focus from school to tertiary level may make the transition more difficult. Around 80 per cent of the students used a graphic calculator (GC) at school, but only 11 per cent of tertiary lecturers used them, and sometimes they are banned at this level. Students said that there was a change from GC use at school, to computer use (such as Matlab) at university. More than half of the teachers did not want to see all calculators used in examinations, based on the belief that students should be able to understand without the use of technology.

Limitations of the research

- The use of a non-probability (voluntary, self-selected) sampling method implies that the samples may not be representative of the two populations. The clear demographics and relatively high response rate may help alleviate these doubts.
- The number of questionnaire responses from Stage 1 students was disappointingly low in spite of our best efforts. The focus group of 35 students doing both secondary and tertiary study were a high ability group rather than a more typical sample of tertiary mathematics students. Hence, there were some differences in opinions between the 35 students from the focus group and the other 42 first year tertiary students.
- This relatively small sample of teacher and lecturer interviews and observations meant that we were unable to make many recommendations on pedagogical practice that might improve transition.
- We were unable to investigate in detail the differences in approach to mathematical concepts and ideas between schools and tertiary institutions.

Building capability and capacity

This research contribute to capability and capacity building by:

- improving the mentoring skills of experienced researchers;
- expanding the research capability of tertiary researchers with some experience and improving understanding and overview of the research process for new researchers;
- improving teacher-researchers' and lecturer-researchers' skills in research design, implementation and data analysis;
- providing insight for teacher-researchers and lecturer-researchers into their own pedagogy, the collaborative research process and issues of transition;
- providing opportunities for research presentations at international conferences for teacher-researchers and lecturer-researchers.

Recommendations

From the results of our study and discussions surrounding them we recommend that:

- the Ministry of Education, The Tertiary Education Commission, all secondary schools and tertiary institutions and other stakeholders look carefully at constructive ways to improve the professional dialogue and the sharing of ideas between mathematics teachers and tertiary mathematics lecturers, both on an individual and group basis. This could include establishment of a national two-way visit programme, a communication channel via a national website, and professional development programmes where members of each sector can be involved in the work of the other.
- all stakeholders consider a mechanism and process for discussing the need for a better alignment of the New Zealand secondary mathematics curriculum in schools with Stage 1 courses at universities. In particular this would include the addition of: topics required at university that are currently missing from the NCEA curriculum (although taught in Cambridge mathematics); the concept of proof; and a common policy on the use of technology, especially calculators.
- schools closely evaluate NCEA mathematics teaching practices and assessment procedures in order to: (a) avoid the practice of leaving out difficult material, either at merit/excellence level or in certain standards, and (b) ensure that teaching inspires students to aim for the highest possible levels.
- the Ministry of Education ensures that mathematics departments are financially supported so that all teachers of mathematics are fully funded to take part in relevant professional development programmes. Whether this should be at universities or other suitable tertiary establishments should be considered. This professional development should include calculus content.
- all secondary schools and tertiary institutions consider instituting organised opportunities for mathematics students to become independent learners within a supportive, collaborative and mentored environment. This could be achieved out of formal class time with the assistance of other students.
- all secondary and tertiary mathematics departments, institutions and professional organisations come together to discuss ways to improve promotion to students of the personal and professional value of mathematics. One area in particular that should be considered is the role of mathematics in society and in careers. A process needs to be established by which school careers advisors and tertiary liaison officers meet and discuss the issues involved.
- all secondary mathematics departments reconsider the importance of conceptual thinking, rigour, applications and problem solving in their mathematics teaching. One possible way to improve rigour would be to look at reintroducing proofs into school mathematics.

- all tertiary mathematics departments re-evaluate the importance of including modelling activity, collaborative work, communication skills, and lecturer-student interaction in their mathematics teaching.
- further research be carried out on best-practice pedagogy in calculus classes at school and tertiary levels in order to make recommendations to improve the transition for students.
- further research be carried out to identify key mathematical concepts in the transition from secondary to tertiary study.

References

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Principal Investigators

Mike Thomas is a Professor in the Mathematics Department at The University of Auckland. His research interests in mathematics education include technology use, advanced mathematical thinking (including theoretical constructs), algebra and calculus learning, teacher knowledge, and links with cognitive neuroscience. He has written over 140 refereed papers and is leading the International Congress on Mathematical Education (ICME) 12 Survey team considering key mathematical concepts in the transition from school to university mathematics.

Dr Sergiy Klymchuk is an Associate Professor in the School of Computing and Mathematical Sciences at the Auckland University of Technology. He has 30 years' experience teaching university mathematics in different countries. His PhD (1988) was in differential equations and recent research interests are in mathematics education and epidemic modelling. He has more than 140 publications including several books published in 11 countries.

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