PROJECT MATHS

Responding to current debate

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NCCA
An Chomhairle Náisiúnta Curaclaim agus Measúnachta
National Council for Curriculum and Assessment

Contents

1. Introduction

In September 2012 all schools are implementing the five strands of the revised mathematics syllabuses. This marks a significant milestone in *Project Maths* – an initiative which began in 2008 to address issues in syllabuses, teaching, learning and assessment of post-primary mathematics.

Project Maths is a work in progress, significant both because of the immense practical, cultural and symbolic legacy that it attempts to address, as well as the weight that is attached to what it aspires to achieve. The aim of mathematics education in schools has always been highly contested, especially when new curricula are being developed or disseminated through a national education system. It is not surprising then, that *Project Maths* is the subject of much debate in Ireland at present. There are always tensions between those who believe the new mathematics syllabus should prepare students for their further study in mathematics and mathematical related disciplines, and those who believe it should prepare students to participate fully in modern society. The former may well be how Leaving Certificate Mathematics, particularly at higher level, used to be viewed by both teachers and students. Smyth and Hannan (2002) noted many students who achieved high grades in mathematics at Junior Certificate did not continue their study of the subject at higher level in Leaving Certificate unless they felt it was needed for third level.

Mathematics is studied by the vast majority of students at upper secondary level in Ireland, which contrasts with the situation in many other jurisdictions where it is an optional subject. As a consequence, mathematics at Leaving Certificate focuses on preparing all students to participate fully in modern society while, at the same time, ensuring that those who wish to progress to further study have the conceptual understanding they need to serve as a foundation for further and deeper engagement in mathematics and related disciplines or careers.

This paper has been prepared in response to current comment on *Project Maths*, notably the UCC *Interim Report on Project Maths*[1] and a paper by Kirkland, Stack et al[2] in which they pointed to what they consider to be major flaws in the revised syllabus. The paper begins by revisiting the origins of the initiative; it sets out the background to, and beginnings of, *Project Maths* – including the research evidence that informed its development. Specific criticisms and issues of current debate are then considered in detail.

1 https://www.ucc.ie/en/media/academic/maths/ProjectMathsInterimReport_Nov2011.pdf

2 http://media.tcm.ie/media/documents/m/MathsCurriculumReport.pdf

2. The origins of *Project Maths*

Context for the review

In 2005 the NCCA undertook a review post-primary mathematics. This was not simply an exercise in syllabus revision but more a fundamental evaluation of the appropriateness of the mathematics that students engage with in school and its relevance to their needs. A number of studies had highlighted concerns (Smyth et al., 2004; Lyons et al., 2003; Elwood and Carlisle, 2003; Smyth and Hannan, 2002).

Key findings from this research were that

- post-primary mathematics education in Ireland featured a highly didactic pedagogy with mathematics being taught in a procedural fashion with relatively little emphasis on problem solving (Lyons, *et al*., 2003).
- the 'new' mathematics curricular culture, with its elevation of abstraction as a core principle, had dominated post-primary mathematics teaching for the last forty years (Oldham, 2001).
- over three cycles of PISA, Ireland had been ranked in the middle of OECD countries in mathematical literacy (OECD PISA reports in 2003, 2005, 2008).

The proportion of students opting for HL and their performance in the state examinations was also a serious concern. Chief Examiners' reports on state examinations in mathematics over a number of years had consistently pointed to the over-reliance by candidates on rote-learned procedures and the lack of deeper understanding of basic mathematics concepts. There was evidence that students were not able to apply mathematical knowledge and skills, except in the most practised way and in familiar contexts.

> *As identified in various previous Chief Examiners' reports, candidates' conceptual understanding of the mathematics they have studied is inferior to that which one would hope for and expect at this level* [LC-HL]*. Whereas procedural competence continues to be adequate, any question that requires the candidates to display a good understanding of the concepts underlying these procedures causes unwarranted levels of difficulty* (Chief Examiner's Report 2005, page 72).

O'Donoghue (2002) pointed to another worrying trend: the low level of mathematical knowledge and skills shown by some students proceeding to further and higher education, and their inability to cope with basic concepts and skill requirements in the mathematical aspects of their courses.

Another element of concern lay in the attitudes towards mathematics in Irish society generally. In a country which has aspirations towards becoming a high-skilled economy, it was a matter of some concern that, culturally, poor attitudes towards and performance in mathematics were accepted as the norm. Many people were negative about mathematics, many children were turned off by it and their school experiences of the subject remained with them throughout their lives.

As part of its review of post-primary mathematics curriculum and assessment, the NCCA commissioned research into international trends in mathematics education[1]. In their research, Conway and Sloane (2006) observed that there was no single template for reforming post-primary mathematics education. There are, however, trends of which the move towards a more 'real-life' focus and emphasis on the development of problem-solving skills is the most distinctive and significant shift in mathematics education in many countries. In addition, they point to a key insight from the TIMSS 1999 video study (Kawanaka, Stigler & Hiebert), where the nature of the links between procedural skills and conceptual knowledge are highlighted as a critically important dimension of high-quality mathematics education.

In addition to the challenges in mathematics education, the broader challenges of a system featuring two external examinations have been well documented. Since the early 1980's there have been several reviews of research on the impact of high-stakes testing on the curriculum (Linn et al., 1982; Crooks, 1988; Koretz, 1988; Koretz et al., 1991; Shepard, 1991; Kellaghan et al., 1996; Black & Wiliam, 1998; Stiggins, 1999; Linn, 2000). There is a strong common theme in the findings: high stakes testing has a backwash effect into daily learning and teaching. This high-stakes impact is universally found to be associated with the practices prevalent in Irish senior cycle mathematics classrooms: teachers focusing on the content of the exams, administering repeated practice tests, training students in the answers to specific questions or types of question, and adopting transmission styles of teaching. In such circumstances, teachers make little use of formative assessment to help the learning process (Broadfoot et al., 1998; Reay & Wiliam, 1999; Osborn et al., 2000; Pollard et al., 2000).

The study of junior cycle mathematics education, *Inside Classrooms* (Lyons, et al., 2003), corroborated these findings and found that these transmission practices also extend to the junior cycle where the stakes are lower. The OECD's TALIS study (2009) found that, while teachers in Ireland reported that they favour a constructivist approach to teaching and

[1] See http://www.ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Review_of_Mathematics/Review_of_Mathematics.html

learning, there was greater classroom emphasis on the use of structured didactic practices and less on student-oriented practices and activities that would require students to explain their reasoning, which are a feature of developments in other countries.

The Eurydice report in 2011 indicates that the trends identified by Conway and Sloane (2006) have continued to be influential across Europe:

> *The research relating to different approaches and methods suggests that there is no one correct way of teaching mathematics, with some researchers arguing that different methods work in different contexts, and others that teachers ought to select the most appropriate method for their context and for a particular learning outcome, and that there may be complex relationships between what works. The conclusion would seem to be that professional development for teachers in a range of different methods, and allowing them to make decisions about what can be applied, when and why, is the best approach for improving teaching.* (Eurydice Network (2011), page 52)

and

> *The use of problem-based learning, exploration and investigation is the focus in a number of countries, as is the use of real life contexts to make mathematics more relevant to the students' own experience.* (Eurydice Network (2011), page 52)

Consultation and discussion

A consultation on the identified issues was held in 2005/2006 with an open invitation for anyone to respond to the range of issues presented in a discussion paper (NCCA, 2005). This paper identified particular areas of concern that needed to be addressed as part of the review, including the uptake of mathematics at the different syllabus levels and the performance of candidates in the state examinations and international assessments. The consultation documentation was made available online and, to facilitate feedback, a consultation questionnaire was prepared that was based on the main issues identified in the discussion paper. An online version of this questionnaire was also made available and a free text messaging service (SMS) was established to encourage as wide an audience as possible to participate in the consultation. Consultation information and documentation was circulated widely, including to all post-primary schools and to the education partners. In particular, third-level education departments and the science/engineering departments of Universities and Institutes of Technology were invited to respond. The NCCA also held discussions with a number of focus groups, including parents' representative groups, the council of the Irish Mathematics Teachers' Association, and at an open meeting in UCC.

A report on this consultation was published in April 2006[2]. Respondents commented on the importance of mathematics education to the individual and to society, as well as its significance as a foundation for other subjects, especially science and technology subjects. Particular areas of concern included

- the over-emphasis on procedural skills and rote learning to the detriment of understanding and application to problem solving
- the erosion of time allocated to mathematics in schools, particularly in the junior cycle
- a declining interest in mathematics and commitment on the part of students to making the effort required to understand the subject
- low levels of understanding on the part of students progressing to third-level education, even among those who had studied mathematics at higher level
- a lack of in-depth knowledge by some teachers of mathematics, who tended to operate in a narrow 'comfort zone'
- the significant and complex challenge that changes in methodology will present for *the system and the need to provide long-term, continuous support for such change.*

Beginning *Project Maths*

Informed by the consultation and the commissioned research, and following consideration of a number of possible approaches, the NCCA proposed the *Project Maths* initiative in 2007. The aim was to improve the mathematical experience of students in the classroom by retaining and reinforcing the central elements and mathematical rigour of previous syllabuses, while at the same time changing the approach and emphasis in teaching, learning and assessment. *Project Maths* calls for more student sense-making, problem solving, engagement in rich learning activities, and conceptual understanding to accompany procedural skill.

The NCCA maths committees were convened to progress syllabus and assessment revision under the *Project Maths* initiative. These committees comprised representatives of second-level teachers, school management bodies and third level institutions, as well as the State Examinations Commission and the Department of Education and Skills. Where further expertise was desirable, additional members were co-opted by Council. This facility was availed of, for example, when the NCCA Board of Studies for Mathematics was established (see the Appendix for membership of this board).

[2] The discussion paper and the report on the consultation are available at http://www.ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Review_of_Mathematics/Review_of_Mathematics.html

The initiative placed the teachers at the centre of the curriculum development process and, in order to adapt the developments in light of feedback from the classroom, it began initially with a small number of schools where changes in the syllabus and examination were phased in. The five syllabus strands were introduced in three stages, as were the corresponding changes in the examinations. Since Project Maths was as much about changing teaching and learning practice as it was about changing syllabus content, it was considered desirable to introduce the changes simultaneously in first year and fifth year. This enabled teachers to embed the changed teaching approaches at both junior cycle and senior cycle simultaneously. It also enabled teachers to see the coherence of the subject across second level and the progression in the development of knowledge and skills as students continue their study of the subject at senior cycle.

Skills development

Skills have become the focus of developments at all levels of education systems around the world. There is a lot of debate about the need for schools to help learners to develop 21st century skills, to create new knowledge and to navigate their way through change, uncertainty and opportunity. Initiatives on the teaching and assessment of 21st century skills originate in the widely-held belief shared by several groups – teachers, educational researchers, policy makers, politicians, employers – that the current century will demand a very different set of skills and competencies from people for them to function effectively at work, as citizens and in their leisure time (Forfás, 2007; Forfás, 2009; OECD, 2009).

Arising from the senior cycle consultations which commenced in 2002, the NCCA set about developing a key skills framework for senior cycle education. The framework sets out five skills identified as central to teaching and learning across the curriculum at senior cycle. These are *information processing*, *being personally effective*, *communicating*, *critical and creative thinking* and *working with others*. These key skills were identified during the review as being important for all students to achieve to the best of their ability, both during their time in school and into the future, and to participate fully in society, in family and community life, in the world of work and in lifelong learning. By engaging with key skills learners enhance their ability to learn, broaden the scope of their learning and increase their capacity for learning. *Project Maths*, informed by international trends, develops key skills by promoting a 'collaborative' culture where mathematics is seen as a network of ideas which teacher and students construct together. Learning is seen as a social activity in which students are challenged and arrive at understanding through discussion. Teaching is seen as a non-linear dialogue in which meanings and connections are explored, misunderstandings are recognised, made explicit and students learn from them.

Cooperative approaches to support learning with understanding

Much research has shown the positive effects of co-operative learning on student achievement (Whicker et al. 1997; Bernero, 2000; Walmsley, 2003; Yamarik, 2007).Two of the ten research-based strategies for improving student achievement in mathematics promoted in the International Academy of Education (IAE) handbook, support this approach:

> *using small groups of students to work on activities, problems and assignments can increase students' mathematical achievements (page 21)…focussing instruction on the meaningful development of important mathematical ideas increases the level of student learning (page 14).*

Knapp et al (1995) identified the following characteristics of teaching mathematics for understanding, one of the goals of *Project Maths*:

- emphasising connections between mathematical ideas
- exploring the mathematics that is embedded in rich, 'real life' situations
- encouraging students to find multiple solutions and focusing students' attention on links between the solution processes used
- creating multiple representations of ideas.

The central role that mathematical thinking should play in mathematics education has been receiving attention, both among educators and in the research community, since as far back as the mid 1980's (e.g. Schoenfeld, 1985a: Silver, 1985). As Schoenfeld says,

> *You understand how to think mathematically when you are resourceful, flexible, and efficient in your ability to deal with new problems in mathematics* (Schoenfeld 1985a page 2)

The alignment of mathematics learning with mathematical thinking is an ongoing feature of mathematics education. According to Lutfiyya (1998)

> *mathematical thinking involves using mathematically rich thinking skills to understand ideas, discover relationships among the ideas, draw or support conditions about the ideas and their relationships and solve problem involving the ideas*.(page 56)

It is not surprising then that the development of mathematical thinking should be an important goal of schooling and of *Project Maths*. Mathematical thinking plays a significant role in the development of mathematical literacy. Mathematical literacy, as defined by PISA, is the ability to use mathematics for everyday living, for work and for further study; the PISA assessments present students with problems set in realistic contexts. The framework used by PISA shows that mathematical literacy involves many components of mathematical

thinking, including reasoning, modelling, and making connections between ideas. The UCC *Interim report* appears to adopt a strongly critical view of PISA, and some of the criticisms of *Project Maths* appear to stem from the authors' concerns about PISA. However, where PISA has a particular focus on mathematical literacy rather than on curriculum, *Project Maths* is concerned with curriculum, teaching and learning, and assessment.

3. Current debate about *Project Maths* – a response

Now that the full syllabus strands in mathematics at both Junior Certificate and Leaving Certificate are being introduced in all schools and we have had a number of years of examination results, there has been increased public debate about mathematics education at second level. Particular areas of concern have arisen in the public discourse and this paper addresses the main points that have been raised in recent times. These have predominantly related to Leaving Certificate mathematics – and almost exclusively focus on higher level. This, in itself, is problematic since it fails to recognise the role that mathematics education plays at earlier stages in the students' experiences. It also narrows the debate to one of mathematics education as preparation for further and higher education. By focusing on the most advanced practitioners, the broader purposes of second-level mathematics education are lost, as are the issues related to general mathematical literacy and the need to overcome the cultural and historical attitudes that have given rise to many of the problems facing mathematics education in Ireland today.

The depth/breadth trade-off

There has been much debate about particular content topics that have been removed from the syllabus. In line with other subjects, the syllabus for Leaving Certificate Mathematics is designed for 180 hours of class contact – typically five class periods per week. Because of the number of subjects taken by a student in Leaving Certificate, this time allocation is considerably less than the time devoted to mathematics in upper secondary education in other countries, where students generally take fewer subjects and a smaller proportion of students generally take mathematics. Since the last change in the mathematics syllabus at Leaving Certificate in the mid-90s, experience in schools has shown that the syllabus, particularly at higher level, was both long and time-demanding. Students recognised this and the less than expected take-up at higher level is at least partially due to their choosing to seek CAO points elsewhere, while achieving the minimum matriculation requirements in respect of mathematics by studying it at ordinary level. The recent surge in uptake at higher level, arising from the awarding of 25 bonus CAO points for achieving a minimum of Grade D in higher-level mathematics, shows that a greater number of students were capable of studying higher-level mathematics at Leaving Certificate.

The breadth of the syllabus needed to be reduced to leave time in the classroom for the development and assessment of conceptual understanding and of the higher-order thinking and problem-solving skills that are so valued in the 21st century, yet which were noticeably absent in candidates' work:

> *Weaknesses, by and large, relate to inadequate understanding of mathematical concepts and a consequent inability to apply familiar techniques in anything but the most familiar of contexts and presentations* (Chief Examiner's Report 2005, page 49).

In deciding on the topics to be retained or removed, care was taken to ensure that students would get a sufficient foundation in the basic mathematical concepts in all of the strands to enable them to build on these at a later stage.

The elimination of choice

A decision was taken to eliminate choice from the examination because previous examination choice had resulted in parts of the course being omitted, with the result that students were unable to make important connections between topics. Another consequence of this choice, allied to the options available in the syllabus, was that students could omit significant topics from their study of mathematics at Leaving Certificate, unaware of the consequences that this could have when they progressed to third-level education. The acquisition of good mathematical skills and understanding was considered more desirable than a procedural treatment of a large range of content. The removal of choice in the examination had been successfully introduced in Junior Certificate Mathematics as part of the syllabus change in 2000.

Issues and concerns

Concern has been expressed by commentators in respect of the following specific topics that were removed from the syllabus:

Vectors and Matrices: In the past, the study of vectors was an option at ordinary level that was avoided by many students; matrices was not part of the syllabus at this level. At higher level, the syllabus content relating to vectors and matrices was treated in a procedural manner with little application or connection to other areas of mathematics**.** To deal fully with these topics would require several months of study and, following discussion with third-level and engineering interests in particular, it was decided to remove these topics entirely and to focus on pedagogical practices that promote the development of skills and conceptual understanding in topics that underpin these areas of mathematics.

Calculus: The treatment of this topic in the revised syllabus has come in for particular criticism, with some commentators suggesting that it has been omitted entirely. A glance at Strand 5 of the revised syllabus, dealing with functions and calculus, will show that the basic principles of both differential and integral calculus have been retained, including differentiation from first principles, the derivatives and integrals of specified functions, and

applications of both differentiation and integration. Some predominantly procedural aspects of calculus, including techniques such as integration by substitution, have been omitted from the revised syllabus at higher level. However, it should be borne in mind that the manner in which these were taught and learned in the past was far from ideal in promoting understanding and application. There is evidence from successive Chief Examiner reports that students were experiencing only a procedural treatment of calculus.

> *Answering indicated that candidates can competently execute the technique of differentiating by rule, (as evidenced by success in part (i)), but are not able to apply their knowledge with any degree of understanding, (as evidenced by their failure to engage meaningfully with part (ii)).* (Chief Examiner's Report 2005, page 32).
>
> *Other than part (i), this was very poorly handled by the majority, despite the fact that establishing an iterative rule for approximating a square root is a standard application of the Newton-Raphson method, and has been dealt with before on examination papers. The widespread inability to handle this question stands in sharp contrast to the fact that candidates normally have little difficulty applying the same method to find a specific approximation of a specific polynomial (a well-rehearsed routine algorithm). This indicates that candidates are not achieving the stated aim of the syllabus that they should be able to apply their knowledge in the context of "the ability to solve problems, abstract and generalise".* (Chief Examiner's Report 2005, page 61).

The need for conceptual understanding was again highlighted in the 2011 examination with students (and many teachers) reporting that they were unable to do a question that required them to recognise a graphical representation of functions of equal derivatives, which was a move away from the predictable type of question asked in the past. Since the ability to move fluently between different function representations is important in the development of conceptual understanding, time to develop this fluency was considered more critical than 'covering' large amounts of predominantly procedural content.

It should also be noted that treatment of some aspects of calculus has been given greater emphasis in the revised syllabus. For example, foundational issues such as limits, continuity, differentiability, as well as careful treatment of function definitions such as injective, bijective and surjective are explicitly mentioned in learning outcomes in the revised syllabus. Emphasis is given to analysis of functions and to applications of calculus in problems that are purely mathematical as well as in applied contexts.

A recent advertisement placed by the Dublin Institute of Advanced Studies for a pre-college course in calculus was critical of the 'severe' reduction in the calculus taught at Leaving

Certificate higher level. The advertised course was aimed at higher-level Leaving Certificate Mathematics students to prepare them for

> *third level courses in Mathematics, Science and Engineering (as well as Economics) and in order to give students with an aptitude for mathematics the opportunity to prepare themselves better for further study* (from DIAS website, www.dias.ie)

The course lists ten 'subjects' to be covered, the majority of which are included in the revised syllabus (under Strand 5: functions and calculus). One advertised topic/subject – Primitive functions and the Fundamental Theorem of Calculus – was not included in the previous Leaving Certificate Mathematics syllabus.

Cognitive challenge in mathematics

Much media comment on *Project Maths* has referred to the 'dumbing down' of the syllabus. Kirkland,Stack et al in their aforementioned paper, refer to the 'watering down' of the Leaving Certificate higher-level syllabus and its knock-on effect at third level. It is a matter of fact that content has been removed, although not to the degree suggested by the Dublin Institute for Advanced Studies among others, but these criticisms do not take into account the changed emphasis on conceptual understanding and the development of problem-solving skills which is advocated under *Project Maths*. Classroom activities that facilitate the development of conceptual understanding and problem-solving skills are not only more cognitively challenging than practising routine procedures to solve predictable problems, but they also promote the development of key skills which are essential for lifelong learning. Students learn to think for themselves, to make connections between different mathematical ideas, and to reason. Jo Boaler, professor of mathematics education at Stanford University in California, recently made the point that young people rarely experience real mathematics:

> *Instead of posing questions, solving real and interesting problems, using and applying methods, investigating patterns and relationships, students spend their time watching a teacher demonstrate methods and then practising them. These kinds of activities involve higher-order thinking and problem-solving skills which are essential for life in modern society* (Opinion piece, The Irish Times, 29th August 2012).

Teacher professional development

The authors of the UCC report refer to the 'enormous burden' of up-skilling that will be placed on teachers as a consequence of *Project Maths*. In planning the initiative, the professional development of teachers was phased to coincide with the introduction of the different strands. However, the thinking behind the initiative is that teachers should continue

to engage in professional development as part of lifelong learning to enrich their professional knowledge, understanding and capabilities throughout their careers. Building the capacity of maths teachers to adopt new approaches in their classrooms and building their confidence and professional expertise are fundamental to educational progress.

As *Project Maths* was rolled out nationally, the programme of professional development provides for ten full-day workshops over five years, with the focus on methodology. In response to requests from teachers for additional support in content knowledge, these workshops were complemented by a range of optional evening courses, run in local Education Centres, which dealt mainly with mathematics topics (content) and/or with using ICT in the teaching and learning of mathematics. These supplementary courses, which were attended by significant numbers of mathematics teachers, were facilitated by trained teachers who were supported in their role and who were drawn mainly from the membership of the Irish Mathematics Teachers' Association.

In addition, elective summer maths courses have been organised at the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL) based in the University of Limerick, to meet the growing professional development needs of teachers. While these were run for teachers from the initial schools and the support personnel, the materials used and developed during these courses were made available to all teachers via a CD (first course in 2009) and on the NCE-MSTL website. Feedback from teachers in the initial schools indicated that collaborating formally and informally with colleagues was the most valuable support in helping them change their practice. As a result, the development of communities of practice is the priority for the support in these schools in the coming year and this development will inform the programme of support nationally in subsequent years. The project originally gave a commitment to supporting professional development of teachers for a minimum of five years; the response of teachers to date shows an enthusiasm for continued engagement in the process of change and for availing of the opportunities that are available to support them in doing so.

In September, a Professional Diploma in Mathematics for Teaching was launched to provide a university accredited qualification at level 8 for 'out-of-field' teachers of mathematics. This two-year, part-time course is managed by the NCE-MSTL and funded by the Department of Education and Skills. Almost 400 teachers are taking the course in its first year, and another two-year cycle will be run again from September 2013.

Text-book issues

Traditionally, mathematics textbooks in Ireland have supported the instrumental, structured approach to teaching and learning described by Lyons et al (2003). An important feature of *Project Maths* is the reduction in emphasis on practising routine or procedural questions and solutions based on illustrative examples, with more emphasis being given to students engaging in problem-solving approaches and justifying or explaining their solutions. Students are encouraged to think about their strategies, to explore possible approaches and evaluate these, and so build up a body of knowledge and skills that they can apply in both familiar and unfamiliar situations.

At all stages of the curriculum and assessment development process associated with *Project Maths*, publishers were briefed on what was emerging. Some of the publishers opted to develop supplementary texts according as the various strands were being phased in; others waited to see the full syllabus before publishing revised texts. In their feedback to the NCCA[3], while critical of the lack of dedicated textbooks for the revised syllabuses, teachers in the initial schools reported that their classroom practice now relies less heavily on using the textbook as the sole teaching resource.

Inter-connection of topics

The UCC report is critical of the lack of inter-connection between the various topics in the various strands. However, this report is based on early drafts of the syllabus strands and this time-position needs to be taken into account. While there may have been less emphasis on inter-connection between topics in the first year of introduction, when just two strands of revised topics were involved, the syllabus makes clear that students should be encouraged to make appropriate connections within and between strands, but also with other areas of learning. One of the main principles of *Project Maths* is that mathematics should be taught in contexts that allow students to make connections within mathematics, between mathematics and other subjects, and between mathematics and its application in the real world. Establishing connections across the syllabus proved a challenge for teachers due to the phased nature of the change, as reported in their feedback at school meetings with NCCA personnel. A strong emphasis is now being placed on developing connections between topics and strands, and this is made explicit in the syllabus. Teacher support is focusing on how best to organise the sequence of teaching to allow students to develop the connections. This approach was also taken in developing the Common Introductory Course as a minimum set of topics across the different syllabus strands to be studied in first year.

[3] *Project Maths: Reviewing the project in the initial group of 24 schools* – report to Council on school visits. See www.ncca.ie/projectmaths

Information meetings for third-level personnel

Meetings have taken place with those involved in initial teacher education in the third level colleges so that their courses can be adapted to fully prepare newly qualified teachers in both the content knowledge and pedagogical knowledge required to engage with the revised syllabuses. Information/discussion meetings have also been held in third-level institutions so that academic staff could be informed about the developments in post-primary mathematics and have the opportunity to consider the implication of these for students who are progressing to third-level education – whether that be in courses that contain significant study of mathematics or courses in which there is little mathematical content. Further meetings of this nature are being planned.

4. Concluding remarks

As indicated at the outset, *Project Maths* is a work in progress. It has proved to be a challenging experience for students, teachers and schools. The comfort of well-rehearsed classroom practice that has served well over the years, the style and predictability of examination questions, and the relatively steady stream of 'good' results achieved have meant that the scale of change required under *Project Maths* came as a shock to the system. When teachers in the initial group of schools were asked to consider how their classroom practice has changed as a result of engagement in the project, many noted that they had achieved significant change, while others saw themselves as having a long way to go[4]. While they recognised that the road ahead is a long one, increasingly, it is a road that they can see the point of being on. The can see improved engagement on the part of their students and, in general, would not want to go back to 'the old way'.

Students, too, have found the change difficult and disorientating, not least the unpredictability of examination questions and the context-based problems. However, on the other hand, they have become more involved in discussing mathematics problems, in making sense of the maths they are studying and in some cases deepening their mathematical knowledge and building their confidence.

Project Maths as a curriculum and assessment initiative has also proved challenging for the system more generally. The developmental nature of the syllabus revision process, the phasing of the introduction of the syllabus strands, the unprecedented scale of teacher professional development and support, the challenge of generating examination papers that really probe the kinds of understanding which *Project Maths* is trying to achieve have all proved to be a significant challenge. However, there are encouraging signs of progress towards achieving the vision of a change in mathematics education that is fundamentally for the better, and for all.

Like any significant change initiative, it requires some time before its impact can be evaluated. The NCCA is continuing to monitor the progress of the project, through its engagement with schools, with the team involved in professionally supporting teachers, and through its committees. The National Foundation for Educational Research (NFER) based in the UK has been commissioned to evaluate the impact of the project on student learning, achievement and motivation. There are four main phases to the NFER research:

[4] *Project Maths: Reviewing the project in the initial group of 24 schools* – report to Council on school visits. See www.ncca.ie/projectmaths

- internationally comparable assessment of students' achievement in all strands of the revised mathematics curriculum, based on indicator items administered to two separate cohorts of Junior Certificate and Leaving Certificate students in Spring 2012 and Autumn 2012 (examination classes of 2012 and 2013, respectively)
- attitude surveys exploring students' experience of the revised mathematics curriculum and their confidence and motivation in mathematics, administered to two separate cohorts of Junior Certificate and Leaving Certificate students in Spring 2012 and Autumn 2012 (examination classes of 2012 and 2013, respectively)
- ongoing data-rich case studies in eight of the initial 24 schools, and eight of the national rollout schools, exploring in depth students' and teachers' experiences of the revised mathematics curriculum
- qualitative analysis of students' work exploring trends in the processes being promoted in the revised mathematics curriculum and its impact upon individual students' progress, which will be conducted in Autumn 2012 focusing on the Junior Certificate and Leaving Certificate examination classes of 2013.

An interim report on this DES-funded NFER research will be published in Autumn 2012, and the final report is due to be published in May 2013.

In cooperation with the Higher Education Authority, the NCCA plans to hold a conference on mathematics education early in 2013, so that the debate can extend beyond discussion of specific curricular issues at second level and lead to a clearer and shared understanding of the role of mathematics in the broader sphere of education and the contribution it makes to the development of the individual and of society.

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6. Appendix

NCCA Board of Studies for Mathematics 2009-2011

Name			Nominated by
Mr	John	McGuinness	ACCS
Ms	Brigid	Cleary	ASTI
Mr	Christy	Maginn	ASTI
Dr	Seán	Delaney	Co-opted
Dr	David	Flannery	Co-opted
Dr	John	O'Donoghue	Co-opted
Mr	Tom	O'Connor	DES
Dr	Patrick	Murphy	HETAC
Mr	Frank	Turpin	IBEC/Council
Dr	James	Grannell	IUA
Mr	Seán	Ashe	IVEA
Ms	Mary	Keane	JMB
Ms	Mary	O'Neill	JMB
Mr	Hugh	McManus	SEC
Ms	Imelda	Moloney	TUI
Mr	Seán	Connolly	TUI