AN EXPLORATION OF ATTAINMENT IN LEAVING CERT MATHEMATICS, AND CORRELATION, IF ANY, WITH PROGRESSION FROM FIRST YEAR CIVIL ENGINEERING IN GMIT

ABSTRACT

The 'Mathematical Problem' has been reported and discussed extensively in Ireland and internationally for the last twenty years. This problem relates to students entering numerate disciplines, such as Engineering, and the decline in basic mathematical skills and level of preparation on entry into Higher Education. This decline presents a major challenge for mathematical based degree courses.

This paper reports on a case study of progression in first year of the Bachelor of Engineering in Civil Engineering Ordinary degree programme (Level 7) in Galway-Mayo Institute of Technology (GMIT). This study analysed progression for the three previous academic years (2009-12) to determine if there was any correlation between progression and prior attainment in the Leaving Certificate Mathematics. Interview records of students who registered for the programme, conducted annually during induction, formed the basis for the study. The students who progressed from first year were also surveyed to determine their opinions on progression and measures to improve non-progression in first year. A review of strategies related to mathematics, adopted by other Engineering programmes, to improve progression is also considered.

The analysis of progression, for this case study, suggests a strong correlation between attainment in mathematics in the Leaving Certificate and progression in first year of the Civil Engineering programme in GMIT. Furthermore, the research suggests that students with low attainment (less than B in Ordinary Level) are unlikely to progress beyond first year. The survey of the students, who did progress, indicated that they are acutely aware of the importance of mathematical competency in engineering.

The results of this study make a compelling case for the introduction of a minimum entry requirement for LC mathematics for admission to the Civil Engineering programme in GMIT.

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1. Introduction

The issue of progression in higher education is becoming increasingly important in Ireland and internationally. The HEA report, *A Study of Progression in Irish Higher Education*, stated there is a clear and strong link between prior educational attainment and progression in higher education (Mooney, Patterson, O'Connor, & Chantler, 2010). In particular, the report notes that attainment in Leaving Certificate Mathematics is the strongest predictor of successful progression among higher education students.

The aim of this study is to explore attainment in Leaving Cert Mathematics and correlation, if any, with progression from first year of the Bachelor of Engineering in Civil Engineering Ordinary degree programme (Level 7) in Galway-Mayo Institute of Technology (GMIT). In recent years, similar to other programmes in the Built Environment, there has been a reduced student demand for the Civil Engineering programme in GMIT. This has resulted in reduced CAO entry points and a significant increase in non-progression in first year of the programme. This case study relates to students who registered for the programme over three years (2009-2011) and to their progression in first year. It is hoped that this study may inform the upcoming Programmatic Review for the Civil Engineering programme and may stimulate further research in Engineering education in GMIT.

This paper reviews the literature in Ireland and abroad in relation to competency in Mathematics, its influence on engineering in higher education and predictors for progression in engineering programmes. The analysis of student progression and attainment in Mathematics will be critically assessed based on the data from three years of registered students on the Civil Engineering programme. The survey results based on the opinions of the current Civil Engineering students will also be reviewed to determine if there are any predominant factors suggested by the students for non-progression in first year. Recommendations and conclusions based on this research case study will be presented at the end of this paper.

2. Literature Review of the 'Mathematics Problem' and Progression in Engineering in Higher Education

2.1. The 'Mathematics Problem'

Issues related to the 'mathematical problem' have been reported and highlighted in a wide variety of publications in Ireland and internationally for the last twenty years (LMS, 1995; Barry M. , 1997; Evensky, Kao, Yang, Fadele, & Fenner, 1997; Barry & Davis, 1999; Smith, 2004; Hourigan & O'Donoghue, 2007). To summarise, the reports comment on the decline in basic mathematical skills and level of under-preparedness of students entering mathematical based degree courses, such as engineering. This has posed significant challenges for higher education institutions and required programmes to adapt or revise the manner in which they are delivered.

In the UK, a report by the Engineering Council (Hawkes & Savage, 2000) reported on the 'serious decline' of mathematical competency and level of preparation for mathematics-based degree courses. In Australia, it is reported that the decline in standard in school mathematics is impacting on students entering third-level science and engineering courses and may, eventually, lead to sections of industry with a lack of suitably trained graduates (Senate Comm., Commonwealth of Australia, 2007). The National Mathematical Advisory panel was established in 2006 in America to foster greater knowledge and improved performance in mathematics among American students (National Mathematics Advisory Panel, 2008) because of reported decline in mathematical competency of American students when compared internationally.

The OECD's Programme for International Assessment (PISA) assesses the knowledge and skills of 15-year-olds in a number of areas, including mathematics in three-yearly cycles. In the 2009 PISA study (PISA, 2009), Ireland ranked 32nd among 65 participating countries and 26th of 34 OECD countries for mathematical literacy. Ireland's performance in mathematical competency was the second largest decline amongst countries participating in 2003 and 2009 (Perkins, Moran, Cosgrove, & Shiel, 2010).

In Ireland, the Expert Group on Future Skills Needs (EGFSN) made a number of proposals at improving mathematical proficiency and noted that mathematics was fundamental requirement for Ireland's development as a modern economy (EGFSN, 2008). The

introduction of Project Maths to the Leaving Certificate (LC) syllabus was in response to the low number of students undertaking higher-level LC mathematics and to change the way in which Mathematics is taught and assessed. The LC examination in 2012 was the first year in which the majority of students undertook the new Project Maths syllabus and therefore it is too early to see the impact it will have on in higher education.

2.2. Mathematics and Engineering in Higher Education

Mathematical proficiency underpins many third level programmes but it is particularly important to numerate disciplines such as Science, Technology, Engineering and Mathematics (STEM). The apparent decline in basic mathematical skills as noted above has a more pronounced effect on mathematical-based degree courses such as engineering (Kent & Noss, 2003; Parsons, 2004). Mathematics plays a central role in the development of engineers, with respect to entry requirements to some undergraduate courses, and as a significant element to many modules on undergraduate courses.

In Ireland, applicants for Honours degree Engineering programmes (Level 8) in the University sector must have at least a 'C3' grade in Higher Level Mathematics in the Leaving Certificate. However, there is also an alternative entry route whereby applicants may pass a 'Special Engineering Entrance Examination in Mathematics' for those who do not have the required Mathematics grade in the Leaving Certificate. In the Institute of Technology sector, Ordinary degree courses (Level 7) do not have entry requirements in relation mathematics provided the applicant passes the Ordinary Level LC Mathematics examination.

Another important factor is the wide range of mathematical ability of students entering engineering programmes which means it can be difficult to structure some modules to meet the abilities of all students. The competency of undergraduate students in mathematics is critical in their engineering education and is also fundamental to student retention and progression within engineering courses.

2.3. Predictors for Progression in Engineering Programmes

The HEA Report, *A Study of Progression in Irish Higher Education*, studied the progression of fulltime students in the Irish higher education system between 2008 and 2009 (Mooney et al., 2010). This significant body of statistical research provides a comprehensive snapshot of progression in all programmes in Irish higher education. The report provides the most

complete picture of the progression in third level education to date and will be used as a baseline for future research in this area. The strong correlation between mathematical competence, as reflected in the Leaving Certificate examination results and the likelihood of progressing was highlighted in the report. Research conducted in DIT indicated that LC mathematics grade is a key determinant in the progression of a student through engineering programmes (Russell, 2005).

Statistical analysis of third level students in Ireland and abroad has recorded levels of non-progression in engineering programmes well above the national average (HESA, 2006; Mooney et al., 2010). The first most comprehensive report on non-completion in the IoT sector noted that almost half of engineering students did not complete their studies (Eivers, Flanagan, & Morgan, 2002). The difficulty with the large statistical analysis of students in higher education is that they sometimes lack the level of detail required to understand why students fail to progress within specific disciplines. The reasons for non-progression are complex and there is generally no one reason why students withdraw from programmes. Reviewing the wide body of literature on student retention within engineering and summarised by Heywood (Heywood, 2005), the majority of research has concentrated on statistical analysis, surveys and qualitative studies.

A study of first year engineering students in the University of Michigan concluded that the key predictors for progression were: entry qualifications, quantitative skills, commitment to an engineering course and confidence with the use of engineering skills (Veenstra, Dey, & Herrin, 2009). In Loughborough University (UK), a statistical study conducted by Lee (Lee, Harrison, Pell, & Robinson, 2008) utilised a mathematics diagnostics test to assess the students prior mathematical knowledge, when commencing a mechanical engineering programme and to predict the students' first year performance using statistical regression models (statistical package SPSS was used). The models considered 14 variables but in the models developed, three factors emerged as being significant; the performance of the students in a mathematics diagnostic test, then the number of statistics modules studied at A level and whether the students attended the mathematics learning support centre. The study indicated that attendance to a Mathematics Learning Support Centre (MLSC) was shown to have a positive effect on all students within the course.

Some argue that a mathematics diagnostic test may provide a more complete tool for assessing students entering an engineering programme and also a better predictor for future performance rather than prior education attainment in mathematics. In the UK, at least 60 departments give diagnostic tests in basic mathematics to their undergraduates (Hawkes & Savage, 2000). Diagnostic tests can be used to identify students at risk of failing because of their mathematical deficiencies, help to target remedial help and assist in design of programmes and modules that take into account the general levels of mathematical attainments. Undertaking diagnostic tests and then offering appropriate support has become a valuable strategy implemented on a number of third level programmes which has shown encouraging results with regard to improving progression of students in first year.

A review of 15 institutions in the UK with respect to their approach to mathematics in engineering education (Reed, 2003) reported that the similar strategies were adopted to assist engineering undergraduates in attaining mathematical competency. There was universal agreement that on the whole students were ill-prepared for the mathematical input of their chosen courses. It was stated that students must be able to see the relevance of maths to their branch of engineering and therefore the maths syllabus must be discipline specific.

Since the 1980s, higher education institutions in Ireland have carried out diagnostic testing to assess the mathematical competency of their undergraduate engineering students. These tests have shown that many students have significant problems with core mathematical skills (Cleary, 2007; Gill & O'Donoghue, 2007). In response, Ireland's first Mathematics Learning Support Centre opened in UL in 2001 and it was modelled on the Centre established in Loughborough University. The centre uses diagnostic testing to identify and support students, as well as for research purposes. Similar support centres have been established in other institutions. A Mathematics Support Centre (MSC), in the National University of Ireland Maynooth, had a positive impact on grades and appears particularly beneficial to students with weak mathematical backgrounds (Mac an Bhaird, Morgan, & O'Shea, 2009). Research in DCU looked at the pass rates of at-risk students at DCU, and concluded that their Mathematics Learning Centre (MLC) made a positive contribution to student retention (Dowling & Nolan, 2006).

In addition to the level of mathematical skills needed at entry to engineering courses, it is also clear that the higher education sector in Ireland (Universities and IoT) needs to review the

teaching of engineering modules in order to allow students with different mathematical skills at entry to prosper.

3. Research Methodology

Research for this GMIT case study was based on records of interviews of first year students who registered for the Civil Engineering programme in 2009-2011. Each year in September, during induction week, all students who register for the programme are interviewed by lecturers to assess their knowledge of Civil Engineering, their motivations for choosing the course, CAO points and attainment in the Leaving Certificate.

This research study is based on interview records of 111 students who registered for the Civil Engineering programme over three years. The analysis focuses on attainment in Mathematics in the Leaving Certificate and progression in first year and does not consider other factors such as CAO points. Students who have not completed the Leaving Certificate Mathematics such as international students and some mature students are not included in the study. Using the 111 interview records, 87 students had completed the Leaving Certificate and their results formed the basis for the analysis.

In addition to the interview records, the students who progressed from first year in the three years analysed (2009-2011) and are still currently registered on the Civil Engineering programme were requested to complete an online survey which consisted of 10 questions. The students surveyed are currently in years 2, 3 and 4 of the Civil Engineering programme in GMIT. The students were surveyed to determine their opinions on the reasons for students progressing in first year on the programme. 39 students completed the online survey which was a response rate of 81%. The survey consisted of a number of short questions, in which the students were asked to give their opinion on progression and non-progression in first year of the Civil Engineering programme in GMIT.

In the survey, students were asked to provide their LC Maths grade, CAO points, CAO preference for Civil Engineering in GMIT in addition to the following questions:

(a) What was the most difficult aspect of first year in GMIT?
(b) Which module in first year Civil Engineering did you have the most difficulty with?
(c) What factors influenced your progression in first year Civil Engineering?

(d) In your opinion, what are the primary factors for high attrition in first year Civil Engineering?

(e) Is there anything that GMIT could do to improve progression in first year Civil Engineering?

4. Analysis of Mathematical Attainment and Progression

For the period analysed, a total of 120 students registered (interview sheets were available for 111) for the programme and the average progression rate was 45%. Although the rate of non-progression is very high, it should be noted that in the period considered the CAO entry points for the programme declined from 350 points in 2009 to 180 points in 2011. Although the reduced CAO entry points are not directly responsible for the poor progression rate, it is clear that the academic ability of the students entering the Civil Engineering course has reduced and that this has a direct link with the mathematical competency of students entering the programme.

The dramatic decline in the CAO entry points is primarily related to demand for third level programmes related to the Built Environment. Since 2008, all programmes related to Construction and the Built Environment in higher education has experienced significant decreases in CAO applications and consequently reduced CAO entry points. Table 1 summarises the number of students and progression rate for the programme in Year 1 for the 2009-2012, CAO entry points and the mean CAO points of the first year students.

	2009-10	**2010-11**	**2011-12**	**2009-2012**
No. of Registered Students	40	46	34	120
No. of students who progressed to 2nd year	23	14	17	54
Progression Rate (%)	58%	30%	50%	45%
CAO Entry Points	350	265	180	
Mean CAO Points	425	360	320	

Table 1 Summary statistics of first year Civil Engineering in GMIT (2009-2012)

The overall progression rate of 45% in the Civil Engineering (Level 7) programme in GMIT for 2009-12 cannot be compared directly with the national figures from the HEA report on progression in 2009 (Mooney et al., 2010) as the report does not consider specific disciplines. The report notes that the 'non-presence' rate in first year in Level 7 programmes in the IoT sector for 'Construction & related' is 20%. However, this figure is not meaningful for comparison as it includes a number of construction related Level 7 programmes including Civil Engineering.

As noted previously, in a number of studies in Ireland and abroad, prior attainment in Mathematics is a very strong predictor for progression in higher education. The results of the analysis of the students who progressed from first year and their attainment in the Leaving Certificate Mathematics are striking. The analysis is based on 87 students and the progression rate for the cohort analysed is the same as the total number of students registered (45%). The 31 students who do not form part of the analysis are those who did not have a LC mathematics grade; international students and students for whom no interview was recorded.

A minority of students analysed (15%) had completed the higher level LC mathematics. The HEA report on progression quantifies the number of students with a C3 grade or higher in higher mathematics and an A1 in Ordinary level mathematics (60+ CAO points) with respect to the third level sector (L6, L7, L8) and also with regard to technology disciplines. It states that only 7% of students entering Level 7 programmes in the IoT sector have obtained 60+ points in Mathematics. For this case study, the number of students with 60+ points was 20% which is expected given that applicants to Civil Engineering would have greater competency in mathematics than the average student registering for a Level 7 programme.

Table 2 and Figure 1 compares the progression rates of students with their attainment in the LC mathematics. In recent years, the number of students entering the programme with higher level mathematics has declined in line with the decrease in CAO entry points. The progression rate for students with higher level mathematics is 77% (10 out of 13). The progression rate for students with ordinary level mathematics is 39% (29 out of 74).

Grade (LC Maths)	No. of Students	Progress	Progression Rate
A (H)	0	0	n/a
B (H)	1	1	100%
C (H)	5	5	100%
D (H)	7	4	57%
A1 (O)	4	3	75%
A2 (O)	5	4	80%
B1 (O)	15	7	47%
B2 (O)	11	6	55%
B3 (O)	4	2	50%
C1 (O)	11	6	55%
C2 (O)	6	0	0%
C3 (O)	5	0	0%
D1 (O)	6	0	0%
D2 (O)	6	1	17%
D3 (O)	1	0	0%
Total	**87**	**39**	**45%**

Note: H = Higher Level, O = Ordinary Level

Table 2 Comparison of Progression with LC attainment in mathematics

The most striking aspect of the analysis is the almost uniform non-progression of students with LC grades less than C1 in Ordinary Level Mathematics. Only 1 of the 24 students (4% progression rate) who entered the programme with less than a C1 (O) grade in mathematics progressed to second year. Although not considered in this study, this point can be further emphasised by noting that no student who commenced their studies in 2009-12, with less than a C1 (O) grade in mathematics, obtained an award from GMIT in Civil Engineering (ie. Higher Cert or above).

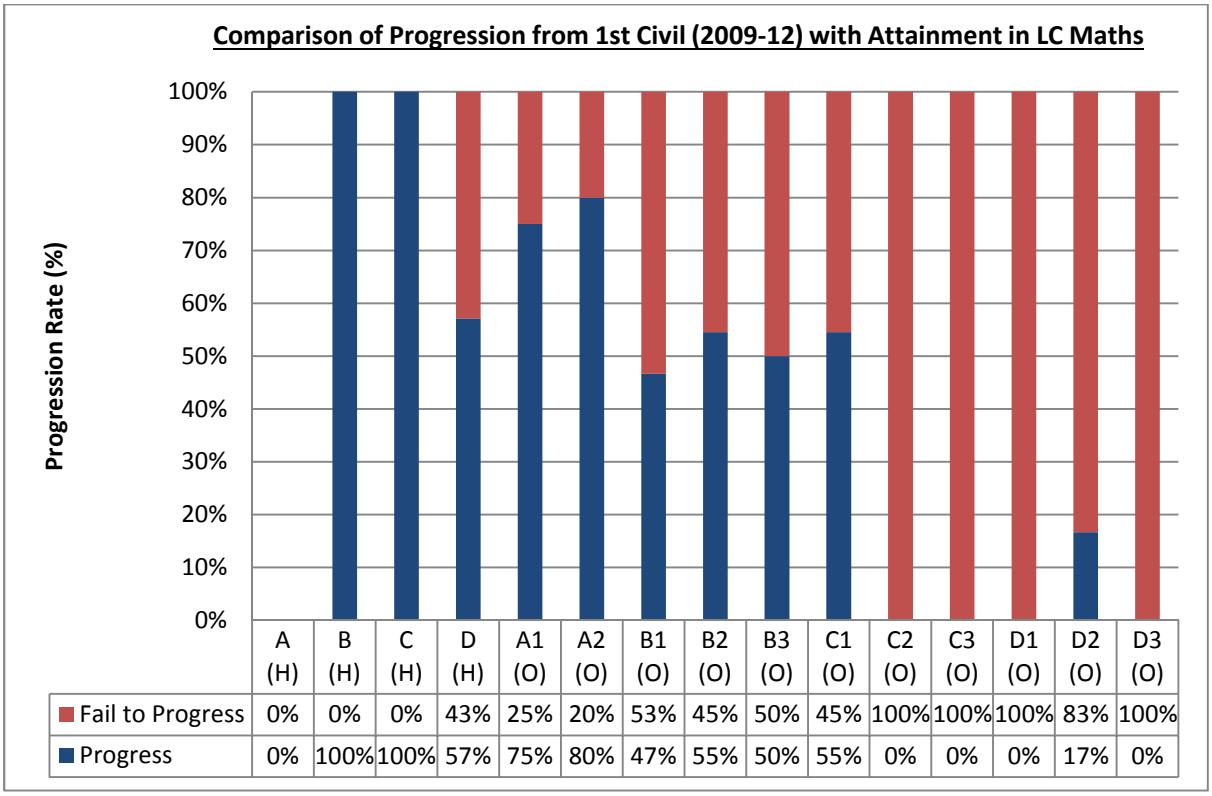

Figure 1 Comparison of Progression with attainment in LC maths

5. Survey of Students

An online survey was conducted with 2nd, 3rd and 4th year registered students on the Civil Engineering programme in GMIT, who had completed first year Civil Engineering in GMIT. These students are primarily composed of the students who progressed from first year in 2009-2012 and therefore their opinion was sought on the factors affecting progression in first year and how retention on the programme could be improved, particularly in first year. The response rate was 81% (39 respondents).

67 % respondents had selected Civil Engineering as their first preference in the CAO, which suggests that motivation and interest in the course selected has a positive impact on the likelihood of a student progressing beyond first year. This correlates with the response of students to the most important factors for progressing through first as two-thirds of students (67%) identified either 'attendance' or 'motivation'. In the United Kingdom, commitment to course and university have been found to be predictive of success in college (Yorke, Ozga, & Sukhnandan, 1997).

Despite progressing through first year, 'Difficulty with Mathematics' was the most popular answer (33% of respondents) when students were asked to rate the most difficult aspect of first year. This point was further emphasised as 'Mathematics' was selected as the most difficult module in first year (33%), followed by 'Structural Mechanics' (28%) which applies mathematics to analyse structures. When asked for their opinion for high attrition on the civil engineering programme, 28% identified 'competency in mathematics' and 15% chose either 'academic difficulties' or 'wrong choice of programme' (Figure 2). From the author's perspective, the response of the students to measures that GMIT could adopt to improve progression in first year was the most surprising and unanticipated. The two most popular suggestions were the establishment of mathematics learning support centre (31%) and minimum entry requirements in LC mathematics for admission to the programme (26%) (Figure 3). Both proposals are related to mathematics which suggests that the students who progressed from first year become increasingly aware of the importance of mathematical competency in an engineering programme. This is something which a significant number of those students may not have appreciated when commencing their higher education studies but has changed as they progressed.

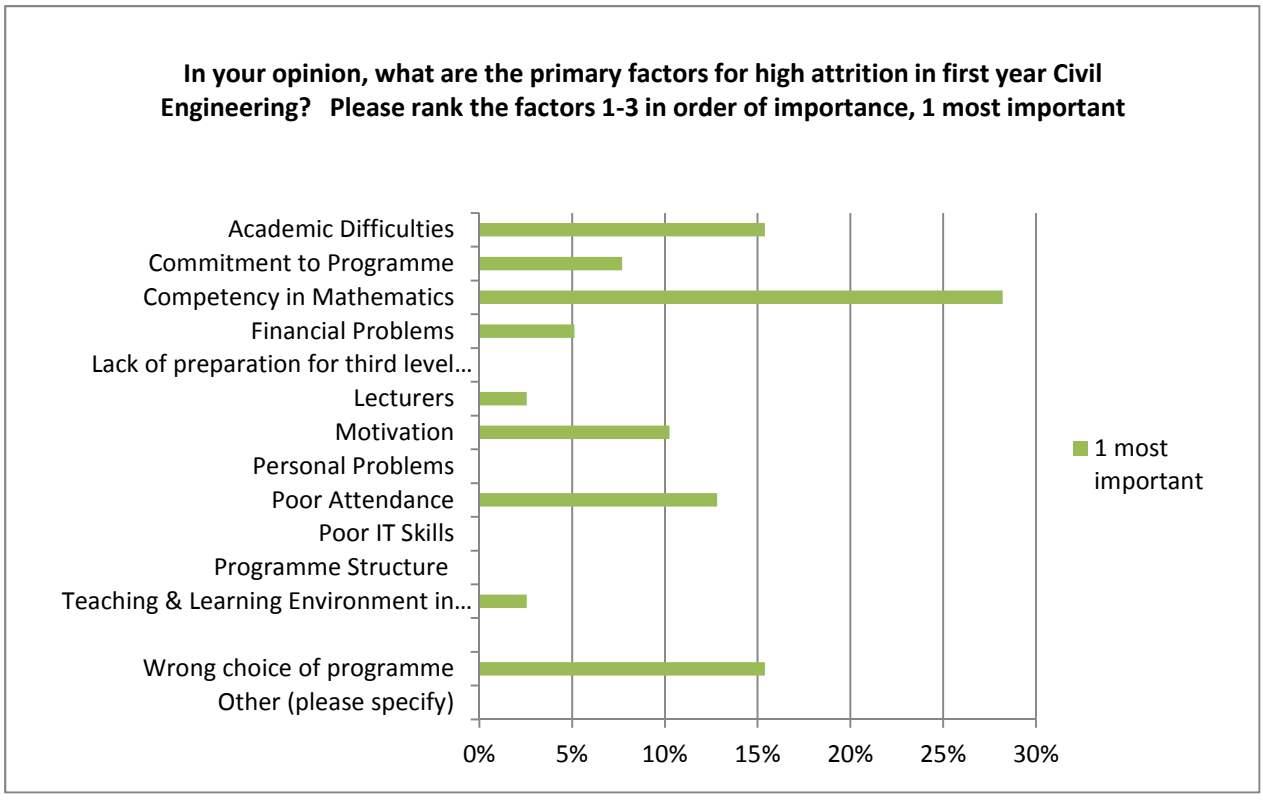

Figure 2 Student Survey - Primary factors for high attrition

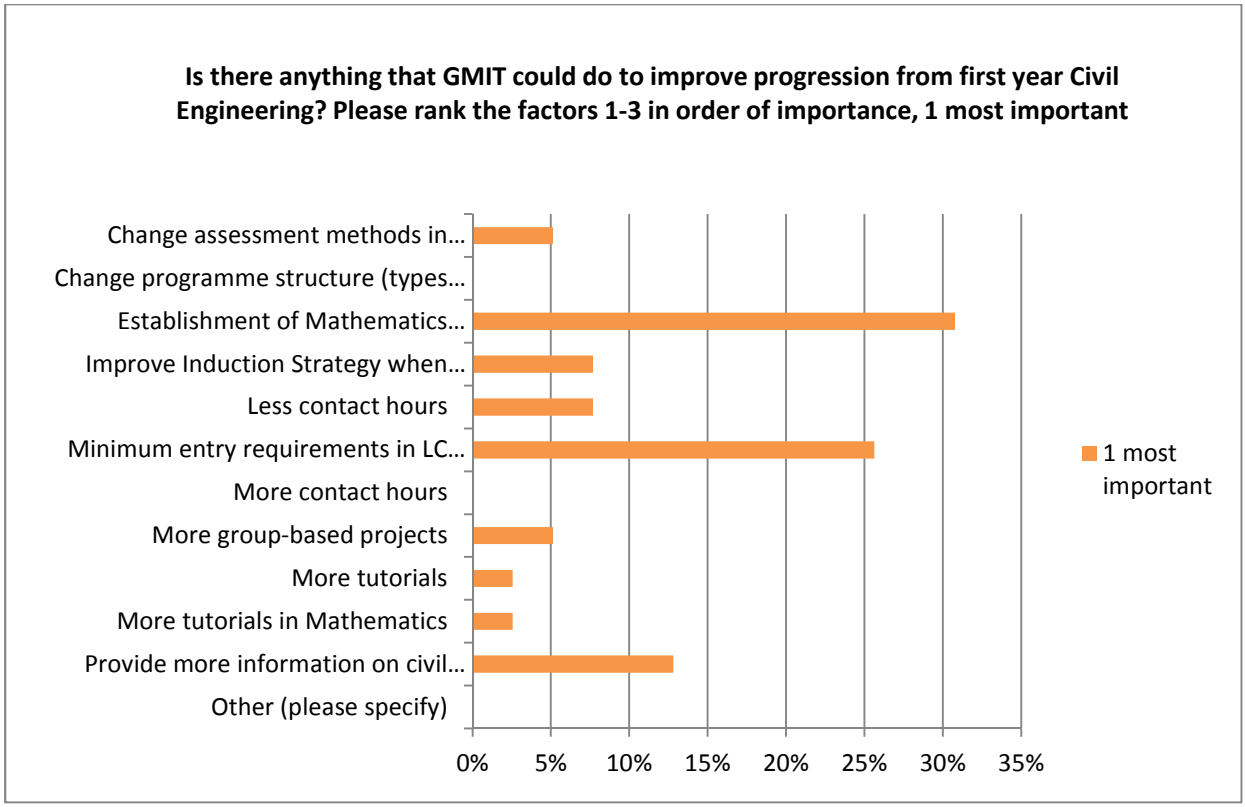

Figure 3 Student Survey – Suggestions to improve progression

6. Conclusions and Recommendations

Although this case study concentrated on one programme within one department of a higher education provider, a large number of the issues highlighted in the analysis and survey may be applicable to other engineering programmes in GMIT and Ireland. The 'mathematical problem' as experienced by staff and identified by students in this survey is a considerable challenge for engineering programmes in higher education and also for second level education. The impact which the recently introduced 'Project Maths' to the mathematical proficiency of students entering higher education will not be apparent for a number of years.

As reported elsewhere, it is important to note that non-progression in higher education is a complex issue and there are a range of factors which contribute towards a student not progressing. This study concentrated on one factor as it was felt that prior attainment in mathematics might be a very significant factor with respect to progression in an engineering programme. The research in this paper clearly identifies a clear correlation between attainment in mathematics in the leaving certificate and progression in first year of the Civil

Engineering programme in GMIT. It would be expected that programmes which require a high degree of mathematical competency, such as engineering, would have some correlation but the results of the analysis described herein indicate strong correlation between attainment in LC mathematics and progression. No student who entered the programme for three years (2009-2012) with less than a C1 (O) grade in mathematics obtained an award from GMIT in Civil Engineering. These results make a strong case for the introduction of a minimum entry requirement for LC mathematics for admission to the Civil Engineering programme.

The online questionnaire gives a student perspective on the issues affecting first year students and factors related to attrition. The survey emphasised that students who progress are conscious of importance of mathematical competency on the Civil Engineering programme and their suggestions for improving attrition in first year (maths support centre and entry requirements) indicate some understanding of possible solutions to the high attrition in first year. In contrast, it is clear from the literature, that the majority of students commencing engineering programmes are not aware of the role and significance of mathematics in engineering.

It is expected in the coming years that there will be low demand from students for all programmes related to the Built Environment and consequently a large number of students with weak mathematical backgrounds will enter the Civil Engineering programme. Programmes such as Civil Engineering must consider how the programme is designed and modules delivered to give the best opportunity for all students to progress beyond first year and obtain an award (Level 6, 7, 8). In particular, it is clear that the programme must adapt to help students who have not had the opportunity to develop the mathematical skills required for an engineering degree programme.

Following this study, the following recommendations are proposed:

- One of the limitations of this case study is that it focuses on one programme. It would be recommended that this study is extended to other engineering programmes in GMIT so that a larger student sample size could be analysed.
- All first years to undertake diagnostic test to identify students with poor mathematical ability and areas of mathematics that are deficient. Following the diagnostic test,

additional support would be provided to students at risk. This may take the form of a Maths Learning Centre or formal extra tutorials.

- Introduction of minimum entry requirements in LC mathematics for Civil Engineering programme. It is felt that this requirement will emphasise the importance of mathematics to engineering to potential applicants and also prevent students commencing the programme who are unsuited to engineering.
- Establishment of sufficiently resourced Mathematics Support Centre in GMIT.
- Development of a system within GMIT for recording and collating data on why students withdraw from programme.

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