IMPLICATIONS OF SECONDARY LEVEL STEM EDUCATION ON ENGINEERING STUDENTS IN NORTHERN IRELAND

Victoria Frazer, Juliana Early*, Geoffrey Cunningham & Colette Murphy

School of Mechanical and Aerospace Engineering & School of Education
Queen's University Belfast, Belfast, BT9 5AH

Abstract: In 2009, the Department of Education and Department of Employment and Learning (NI) issued a report highlighting the challenges faced in ensuring that the supply of Science Technology, Engineering and Mathematics (STEM) qualified individuals continued to grow in response to demand within the local economy. Over the past decade, there has been a steady decline in uptake of secondary level STEM education, and based on workforce demand in the STEM sector there is a significant predicted shortfall in supply over the next decade. The report presented a series of 20 recommendations for action to promote renewed economic growth through STEM, and highlighted shortfalls in STEM education and careers advice particular to the Northern Ireland education sector. This paper presents an overview of the NI STEM report from the perspective of a tertiary level engineering school, and summarises the findings of a survey undertaken by the authors in a bid to understand how this will affect future generations of student engineers. In particular, a stark gender divide has been identified in how careers advice is regarded at secondary level, and there is a clear need for more to be done to assist in decision making processes at all key transition points.

Keywords; Student recruitment, Retention, Secondary level education

*Correspondence to: J.M. Early, School of Mechanical and Aerospace Engineering, Queen's University Belfast, Northern Ireland. E-mail: j.early@qub.ac.uk

1. INTRODUCTION

Over the past ten years, there has been a marked reduction in the percentage of students entering into STEM (Science Technology Engineering and Mathematics) related career paths within Northern Ireland, which has significant consequences for ensuring economic stability and growth in an increasingly competitive marketplace. The recent All-Island Skills Study (2008) highlighted the continuing importance of engineering within the economy (nearly 110,000 jobs in both the North and South of Ireland were based in engineering at the point of survey) and a continuing need to develop these skills has been identified through both the Northern Ireland Success through Skills (2008) and the Tomorrow's Skills (2006) programmes. With this impetus, a joint study was undertaken by the Department of Education (NI) and the Department of Employment (2009) in the Spring of 2007 to examine these trends and to comment on the implications for the future of the NI workforce. While many of the factors observed are common across the whole of the UK (the increasing apathy at younger ages for STEM related subjects, limited careers guidance at key transition points and a general lack of Continuing Professional Development activities for STEM educators at a secondary level were all identified), a number were unique to Northern Ireland, in particular to those relating to student achievement, the
substantial reduction in the numbers taking A-Level Physics and gender balance within the STEM area. These factors have implications for the numbers of students entering into higher education engineering degrees as they all lead to a reduction in the number of suitably qualified individuals, and to this end the School of Mechanical and Aerospace Engineering at Queen's University Belfast has been examining in more details the implications of the findings of this report with relation to the recruitment and retention of undergraduate engineering students.

2. RECRUITMENT AND RETENTION TO STEM

Despite the continuing need for STEM qualified individuals within the workforce, examination of statistics over the past 10 years indicate that there has been a sustained decline in students graduating from tertiary level STEM subjects across the whole of the UK (relative reduction of almost 3.5%), with the most pronounced drop in Engineering and Physical Sciences (Figure 1).

This is apparent across nearly the entire STEM sector, with the exception of those subjects allied to medicine which has seen a remarkable growth across the same period. It is cause for concern when many of the employment forecasts indicate that the largest growth will be in the STEM sector (Figure 2), with significant demand for graduates with a solid physical sciences background (encompassing the skills that an engineering graduate would obtain). By 2020, based on the current rate of contraction of the STEM supply, it is predicted that there will be nearly a 65% shortfall in workers trained in physical science based careers relative to baseline demand. This is particularly concerning in light of new regulations which no longer require a balance of sciences to be taken to a GCSE level within Northern Ireland (introduced 2007) which has resulted in a significant drop in students electing to study all three sciences in some combination to at least GCSE level. In the first year of introduction of this regulation, the numbers registering for GCSE Double Award Science was reported to fall by 16%, accompanied by an increase in entries to the individual sciences - GCSE Physics reported an increase in registrations of 33.3%. However, on balance this actually represents a net-loss of students who are qualified to undertake A-Level Physics of approximately 7%. For the same year, it should also be noted that the relative uptake of GCSE Single Award Science in NI was nearly three times that of the rest of the UK, again representing a significant loss of students into the STEM pathway as this course is not designed to advance students to higher level STEM education. As a solid appreciation of physics is desirable, if not essential to the engineering undergraduate, this
substantial reduction in students undertaking even basic physics education at the age of 14 has the potential for significant impact downstream on intakes into engineering degree programmes.

Figure 2: % Under-supply up to 2020 in physical science based careers in NI (NI STEM report, 2009)

In order to tackle these recruitment and retention shortfalls, the joint study proposed a series of 20 recommendations for action, which can be categorised into four main areas:

- Increased business engagement in STEM education is required.
- Constraints within the STEM education artery need to be alleviated (or, where possible, removed).
- There is a need for increased flexibility in STEM education.
- Government support for STEM education initiatives needs to be significantly improved.

While the report recognised that there were a number of points within the educational pathway at which students were leaving STEM education, the cause of many of these factors is not entirely clear. As the low uptake in physics and low percentage of females entering into STEM are of particular concern as this ultimately reduces the pool of capable individuals suitably qualified to enter into engineering career pathways, ways in which these trends can be addressed, and potentially, reversed, are essential to ensuring that there is a continuing pool of capable engineering graduate passing into the workforce when they are most in demand.

3. SOURCES OF IMBALANCE

One of the key foundations of an engineering degree is a solid appreciation for physical sciences, but the trends in Northern Ireland across the last ten years have shown that the numbers of students in Northern Ireland enrolling for A-Level Physics is dropping dramatically at roughly a rate of 3-4% per annum, despite NI significantly outperforming the rest of the UK in A-Level Physics results. There has been a subtle, but distinctive shift across that time in the combinations of STEM subjects undertaken, with a move towards combinations including biology and chemistry (the numbers of enrolments for a combination of A-Level Biology and Chemistry has risen by nearly 18% over the last ten years) at the expense of the more traditional subjects for engineering (the combination of A-Level Physics and Mathematics has decreased by nearly 20% in the same period). The NI STEM report indicated that a number of these factors could be traced back to early in the educational process (with indications of dissatisfaction with STEM subjects evident as early as Key Stage 3), but while it clear that students are disengaging from
physics at a number of key points within the STEM educational pathway, it is not entirely clear why this is so stark in Northern Ireland in comparison to the rest of the UK.

To attempt to understand this, a sample of ~400 students from Queen's University Belfast were surveyed to examine the experiences of students with secondary level STEM subjects and, in particular, to identify reasons why students were being put off physics at such an early point in their careers. The questionnaire was distributed electronically, with the questions formulated against a number of the recommendations which have been put forward from the DEL/DE joint panel. In particular to students who would be entering into engineering careers, two of these recommendations are of particular interest:

- How clear are the STEM career pathways in Northern Ireland made to secondary level students?
- Is there a quantifiable gender bias in NI STEM education, and if so, is there a clear source?

This initial student survey was then supplemented with interviews with student teachers currently enrolled on the Queen's University Initial Teacher Education course to examine the challenges that teachers face on their first exposure to STEM teaching in the Northern Ireland education system.

![Figure 3 Influences on A-Level subject selection](image3.png)

![Figure 4 Perspectives on Careers Advice in NI (split by gender)](image4.png)

After analysis of the questionnaires, it became clear that there was one issue which was common to nearly all the students questioned. When considering subject selection, beyond aptitude for a subject, the dominating influence was the importance of that subject to a future career pathway (Figure 1). However, there is a general feeling that there is a lack of sufficient information about careers and pathway options available within schools to support this, and students are not always aware of how the subjects selected for study at A-Level would impact on future career choices - 68% of those surveyed did not feel they had received an appropriate level of careers support from their schools during the subject selection processes. The students placed much more value on access to individual careers advice within their schools during these times rather than on the more traditional careers support mechanisms such as careers fairs, workshops and school visitors.
This perceived lack of careers advice becomes even more of an issue when it is examined by gender – 77% of females questioned did not believe they had received adequate careers advice (compared to 55% of males), emphasizing a lack of all round careers support in their decision making processes, much more than the male respondents. From the perspective of students who had undertaken at least one A-Level STEM subject, it was indicated that there is a general lack of information available to them on STEM career pathways combined with a lack of encouragement to progress in STEM subjects. This was particularly prevalent in female students' experience (Figure 4). In both instances (male and female), schools are falling far short of student expectation in the delivery of careers related information.

For those students who considered engineering as a career option (representing 38% of the respondents), there are again significant differences in the responses which were obtained from by gender regarding the careers support that they received in School.

Female students who would have considered engineering as a career option reported that they had less access to engineering-focussed careers information relative to their male counterparts experience (Figure 5). This included less likelihood to have had access to outside speakers to discuss engineering careers (M: 54% F: 34%), and also less likely to have had access to individual engineering careers advice in their schools (M: 86% F: 65%). When asked what they would have found useful when making careers decisions, there is a definite need for individually tailored careers advice, but there are again distinctive differences in the male and female perspectives on useful activities. Female students are strongly in favour of good careers advice and access to careers fairs to help in their decision making processes (which is of concern, as this is something many of them feel has been lacking), while male students would prefer a more rounded approach incorporating visits, speakers, class work along with the careers advice (Figure 6).

As physics has experienced the greatest downturn in numbers relative to the other traditional science subjects (and is core to engineering), the students were questioned about their perception of physics relative to its counterparts. The responses to this were largely similar for both genders (indicating that the main source of gender bias possibly relates to the lack of careers focus attached to the subject rather than the subject itself). On the whole, the student experience of physics was less favourable than its comparitors - physics teachers were perceived as less knowledgeable about their subject, less able to provide hands-on experiences and classes were less fun (Figure 7). 80% of students felt that there was too little careers advice given about how
physics could be used in later life (as opposed to that which was observed linked to Biology and Chemistry), limited encouragement to pursue it (70%) and too little linkage to real life (74%).

![Figure 7 STEM Classroom Experience](image)

The expressed lack of confidence in the ability of physics teachers is interesting, particularly in light of the recently released numbers indicating the make-up of the secondary level STEM teachers in Northern Ireland which indicate that there is a significant shortage of physics teachers - there are less than 200 registered physics teachers in Northern Ireland, which represents less than a third of the overall number of biology registered teachers, and the age profile indicates that nearly 50% of these teachers are approaching retirement (NI STEM report, 2009). This shortfall in teachers is being covered through the use of non-subject specialists at Key Stage 3 – at the time when students are making choices which will influence their future career pathway, and the point at which the first large drain of students from the physical science based pathways was observed. Non-subject specialists taking on this role at such a formative point of the educational pathway is cause for concern given that studies of physics education have demonstrated that there is a clear link between whether the teacher is a physics subject specialist or not and the level of achievement of their students in physics examinations (Smithers and Robinson, 2005).

Some of the comments from the students regarding their careers and their experience of careers advice in Northern Ireland paint a depressing picture, reinforcing the problems with careers information, encouragement and information about pathways:

1. Careers classes focussing on application procedures rather than actual career pathway advice:
   "Careers classes in school were ..... learning how to apply to university"
   "my careers class always focused on applications to university and fees...... however it won't help you choose the career path which is right for you."

2. Lack of encouragement for females into engineering:
   "I went to a girls school where it (engineering) was hardly mentioned. I resented this as I had a particular interest in the subject."
"Girls are seriously not made aware of engineering as a career choice……. I also found that I received not much encouragement with my choice."

3. Careers teachers with pre-conceived notions of career pathways:

"I was .... encouraged to "know my limits" and was not asked my opinions."

"Teacher input was more focused on telling me what they thought I should do rather than helping me make my own choice or even asking me what I wanted to do and encouraging me to follow my instinct……." 

**4. OBSERVATIONS ON STUDENT EXPERIENCES**

The lack of adequate careers advice at an early stage in the educational pathway reinforces the findings of a number of previous studies undertaken by the IET in 2007 and 2008 which indicated that there is a general lack of good quality careers advice available in schools which is having a negative impact on the uptake of STEM subjects. However, this appears to have more significant consequences when examined by gender: female students appear to place significant emphasis on individual careers advice for decision making, much more so than their male counterparts, and were, on the whole, receiving less (or at least had the perception that they were receiving less) career-focussed information in support of their decision making processes. This has a number of consequences that need to be considered:

1. Female students place increased emphasis on careers advice for future planning, but feel they are receiving an insufficient quantity of this within schools.
2. Current trends indicate that future work opportunities are likely to lie in the science and technology field, which currently has a significant gender imbalance in most sectors.
3. Female students require focused individual careers information as early as pre-GCSE subject selection to highlight career pathways and future opportunities to assist them in their career planning, which is currently not in existence.
4. Male students also require this focussed careers advice, but it should continue to be balanced with a range of other careers experiences, including visitors, workshops and careers fairs.
5. All students have a poor perception of the quality of physics education that they have observed – steps need to be taken to reduce the usage of non-subject specialists at formative points within the educational pathway to reduce the numbers shying away from physical sciences career pathways.

When the student teachers were questioned about their viewpoint on these issues, they also echoed the concerns about the abstract nature of many of the secondary STEM level syllabus' and the lack of obvious relevance of the material to future career paths. This reinforced the need for well-structured careers advice in support of this, but many felt that the students were focussing on subject syllabus for selection rather than taking any long term view on potential career opportunities (linked back to the issues with the number of students now moving away from the traditional balanced approach to STEM education). This will require an increasing level of intervention from the careers support staff to encourage students to take a longer viewpoint on the consequences of the choices that they make as early on as GCSE. Following on from the trend in selection of individual sciences at GCSE level and the future negative impact
on A-Level (and university level) STEM subject uptake – the teachers highlighted their experience with many of the science subjects being mutually supporting, and in many instances, the cross-disciplinary learning processes can assist in achievement in each of the individual streams. By limiting focus to one or two of the sciences, the students lose the benefit of the multiple viewpoints (biological, chemical and physical) on common problems, and with this will often have reduced understanding of the fundamental concepts and often resulting in a lack of appreciation of the real world context. A final note of concern from the educators' perspective was the increasing level of assessment which is being introduced into the educational process at an ever earlier point. There was a feeling that subjects were becoming increasingly assessment focussed, with little opportunity left for meaningful exercises to be introduced into the curriculum purely for exploratory learning and linking theory to real life. Particularly in physics, it was noted that many of the practicals at GCSE and A-Level were often abstract and unrelated to the core syllabus. Given the desire of the students to have a better appreciation of the relevance of subjects to careers, this balance needs to be re-examined.

4. CONCLUSIONS

There is little doubt that action needs to be taken with regards the declining numbers entering into STEM careers - while the overall student population undertaking first degrees has been growing over the last ten years, there has been a reduction in the percentage of that population entering into engineering and technology routes. In comparison to the rest of the UK, first degree enrollments in NI in engineering are at 80% of the UK average, and the number of graduations is showing a relative decline of approximately 1% per year. However, it is clear that this is arising from problems much earlier in the educational process, and can be identified as early on as GCSE selection, where some of the key subjects (such as physics) are rapidly on the decline. The core message which has been obtained from students surveyed in QUB and reinforced by interviews with teachers is that students in Northern Ireland are not receiving an adequate level of careers advice and this needs to be re-dressed to attempt to reverse this trend. By having a stronger STEM careers pathway inbuilt into the educational structure, students will have a better appreciation of the long term job opportunities, increasing the potential for growth in the STEM sector at a time when it is needed.

4. REFERENCES

Northern Ireland Skills Expert Group (2008) 'All Island Skills Summary' publication of the Northern Ireland Skills Expert Group, DEL NI