STRATEGIES FOR THE ATTRACTION OF STUDENTS TO ENGINEERING

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ABSTRACT

Ireland, in common with most Western economies, is experiencing a shortage of suitably qualified young people wishing to study engineering. This paper reports on an investigation into some of the factors underlying student choice, and proposes a sample initiative to help increase student interest in entering the discipline of engineering.

Success in mathematics and sciences at a high level in secondary education is necessary for students to be considered qualified for the study of engineering at third level, but a large cohort of such students are opting to study in the health sciences instead – particularly female students. While some of this choice is almost certainly influenced by parental expectations and the social status of such professions, and some is also most likely driven by expectations of large earnings, detailed surveying of student attitudes shed light on the influence of other factors.

Engineering is correctly perceived as having good employment and remuneration prospects. However, a large number of students are unclear about what engineers do – positive contribution is imagined through particular examples such as ‘bridges’, ‘cars’ etc – omitting the significant contribution made by engineers towards societal well-being across a range of other areas. Particularly among female students, the potential appeal of engineering is not in technical achievement per se, but in direct personal impact and interaction with individuals requiring an engineer’s help in some form – much as a doctor is seen to ‘help the patient’, the engineer must be seen to do likewise.

The area of robotic rehabilitation is one in which engineers and doctors have direct interaction with patients. Conditions such as mobility-impaired cerebral palsy require prolonged rehabilitation through the means of occupational therapy, with patients undertaking controlled and repetitive motions which are typically overseen by a health professional such as an occupational therapist. However, motivation to undertake such repeated activity can be problematic, particularly when dealing with sick or otherwise incapacitated children. Concurrently, resource limitations may prevent direct supervision by a healthcare professional. The use of robotic devices enables more variety to be built into the therapy, and for progress on part of the patient to be logged.

The work reported here outlines a sample robotic rehabilitation platform that facilitates clinically useful tasks for the patient, through control of a robotic device at a remote location. Bi-directional video communication through TCP/IP allows school students to partake in the therapy process through construction of the robot and communication with the patient, with both parties expected to benefit from the social interaction. It is envisaged that the tangible and personal nature of the involvement will demonstrate to school children the significant impact that engineers can have on society, at a personal as well as a systemic level, and thus to significantly increase student interest in this field of study.

KEYWORDS: engineering education, rehabilitation, robotics

1. INTRODUCTION

The attraction of students to the study of engineering at third level has become an increasingly important undertaking, with recent economic research[ref?] highlighting the importance of producing engineering graduates and their impact on the financial solvency of a nation. But although employment opportunities for engineers have remained high across the country, Ireland’s second level students are displaying a distinct decrease of interest not only in the study of engineering at third level, but also in second level STEM subjects – is this totally accurate, recent years have seen something of a correction, if not quite an upturn.

This paper presents an investigation of student perceptions with regards to the field of engineering, and also as to what factors are influencing their choices for third level study. Based upon the results of this analysis, a sample coursework module for integration with the second level STEM syllabus is presented – with the aim of depicting an accurate and attractive representation of the engineering field to second level students.

2. CONTEXTUAL INFORMATION

2.1. General Economic Information

There are a number of factors which can be considered influential to a nation's economy. In the past, sectors such as property construction have been considered important to growth in Ireland. But a consensus has since been reached that this area will not provide the basis for sustainable growth for the future of the economy. An investment in education, however, would provide the foundation for the expansion of a knowledge economy – attracting investment from international corporations such as Intel and HP. Research and development in the engineering areas such as manufacturing and biotechnology has already become efficacious in Ireland's economic expansion [1]. The 2005 report, Engineering a Knowledge Island 2020, discusses the relevance of engineering graduates to the country, citing an increase in the number of employed engineers from 19,000 in 1991 to over 40,000 by 2001/2002 – in a nation with 14.8% of its citizens currently unemployed [2], job creation is high priority for the recovery of the economy. In March of 2011, it was stated that there are still 1,200 positions across Ireland for which engineering graduates are required [3] – a strong indicator of the need for an increase in the number of engineering graduates produced within Ireland.

At the moment, Ireland still employs a policy of significantly low corporation tax – most notably a special tax rate of 12.5% for manufacturing industries [4] – a strategy periodically credited with the rise of the Celtic Tiger [5]. But in order for this policy to contribute positively to the nation's economy, industries must also be continuously attracted for establishment and investment in the country. As has occurred for other economies in the past [6], it can be considered that an increase in the production of skilled engineers within a country – coupled with this low-tax incentive – would provide a strong attraction for high-technology investment, particularly in the areas of research and development.

2.2. Education in Ireland

Second level education in Ireland allows for the study of one of three tiers of maths education, including the *Higher level (HL)* option in which an advanced level of mathematics is taught. Students in Ireland complete a set of examinations at the end of second level education referred to as the *"Leaving Certificate" (LC).* Each student submits a list of their desired third level courses, with the results of the LC used to determine eligibility for placement. Presumably due to the high standard of mathematical competence required for the study of engineering, 81% of the degree standard courses across Ireland state that student applicants achieve a minimum of C3 grade (55%) in the HL of mathematics for the LC examinations. While the presence of this requirement can be considered necessary to ensure that students entering the study of engineering at third level have the ability to comprehend the associated mathematical concepts and analysis, it also means that a significant portion of second level graduates are unable to apply for the study of engineering, regardless of their level of interest in the field – leaving engineering courses marketing to less than 13% of the student population. With this significantly limited attraction pool – when compared with other sectors of third level study – the situation serves to highlight the need for innovation and improvement of the promotional techniques for the field of engineering.

3. STUDENT PERCEPTIONS

Since 2001, when 17.5% of second level students applied for courses within an engineering field, the number of CAO applicants opting for engineering has now dropped to 8% in 2012 [7] – despite an overall increase in the CAO applicant cohort.

A survey of 104 male and female fifth year students from three separate second level institutions produced 36 students eligible for the study of engineering at third level. Figure 1 illustrates their personal interest levels in the study of a variety of third level courses [8] indicating that there was a negative response to the field of engineering. Students instead displayed a preference for the study of medically-based fields such as Psychology, Biology and Medicine. This response was mirrored in the 2009 Northern Ireland STEM report, where engineering across the UK experienced the more significant decrease in graduate numbers of all sectors - a drop of nearly 3.5% since 1999, while subjects 'allied to medicine' experienced an increase of over 4% in the number of graduating students [14].

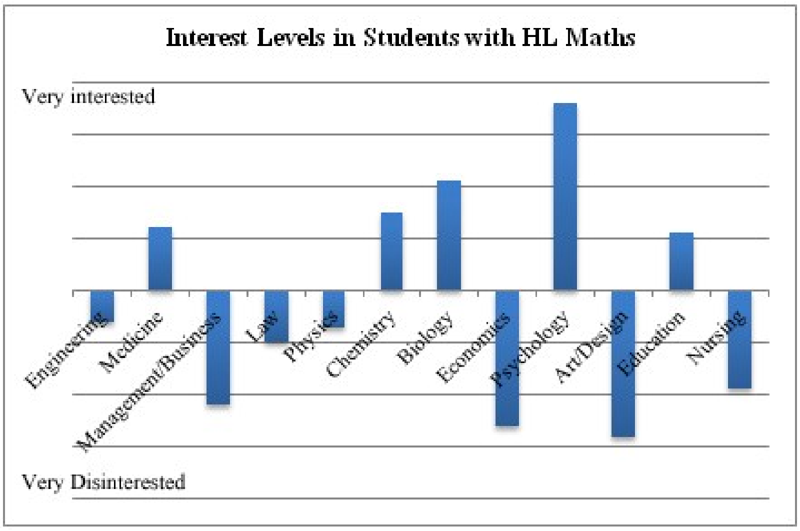

Figure 1: Interest levels of HL Maths students in various third level courses

Results indicating a high level of interest in what could be considered "life-saving" courses correlate with the growing opinion that a primary factor in students' choice of third level study is the perceived social importance of the field [9]. It has been found that the ability to "make a difference" within their chosen field is of particular importance to female students [10, 11, 12], with 'Extraordinary Women Engineers Project' (EWEP) [19] producing the recommendation that in order to attract more female students to the field of engineering, the motivational message of "making a difference" must be highlighted to potential entrants. It may be suggested that the attraction of students to study in the field of engineering may be more efficiently executed on the basis of the personal impact students may make through the field, rather than on traditional technical appeal.

Indeed, factors such as perceived career prospects, course reputation, and past academic performance have been established as key in the decision making process of prospective third level entrants in Ireland [13]. In this 2010 survey 88% of students found to be interested in the field of engineering had studied one or more of the technological subjects available at LC level – such as 'engineering', 'construction', or 'graphical communications and technical design', supporting the theory of a link between students' perception of work in a technological field and their experience of STEM subjects at second level.

4. PBL/CDIO

Students are exposed to a limited amount of practical engineering (or even engineering-relevant content) within their STEM subject education at primary and secondary level – with some studies suggesting that even the second level LC course of 'engineering' is not an accurate reflection of engineering study at third level [12]. Scientific subjects at LC include laboratory work, but experimental procedures presented to the students are accompanied with a list of distinct instructions which the student is required to replicate [**reference**]. There is little scope for the student to develop skills such as investigative learning, research, data analysis or problem-solving – key elements of the engineering field. Without the opportunity to experience these elements, students develop from an early age the perception that engineering is an overly theoretical, maths-centric "desk-job" in which only extraordinarily intelligent people may become successfully or happily employed, and the increasing prominence of this negative perception of engineering across Ireland has been reflected in the decrease in the number of applicants for study in the field of engineering.

As such, it can be considered important to improve the representation of engineering within the second level syllabus. Elements such as problem-solving and research-based group-learning may be illustrated by means of collaborative problem-based learning (CPBL) activities and an increased adherence to the Conceive-Design-Implement-Operate (CDIO) ethos within second level curricula – exercises already shown to be effective in creating an engaging learning environment where the social involvement of the student is highlighted [17, 18]. It has already been stated that when STEM subjects are appropriately taught to students, they can be perceived as challenging and intellectually stimulating, but when these topics are poorly taught they become 'burdensome and irrelevant' [15]. A study of ~400 students of Queen's University Belfast showed that 80% of surveyed students believed there to be too little emphasis on how physics theory may be utilised within a career environment when compared to the fields of biology and chemistry [16], with 74% stating there to be too little relevance to real-life applications within the taught physics curriculum. An increased emphasis on the practical applications of STEM theory would serve to add relevance to second level subjects currently presented in a transmittal and often overly theoretical manner.

5. CONCEPT STRUCTURE

This brings to light the need for the introduction of PBL to STEM education at second level. Students would benefit from the opportunity to be educated in the skills of teamwork and problem-solving, highlighting primary factors of engineering study at third level. Presenting a more accurate and sociable depiction of the engineering field to students at second level would also serve to increase public awareness of what is involved in an engineer's career. It would be necessary to adhere to the national STEM curricula, so that the overall framework and syllabus content of these subjects may be maintained. Yet presenting the syllabus in a manner adhering to the CDIO framework, in which students are expected to implement and utilise theory learned, would serve to improve student motivation towards theory-absorption – highlighting the application and overall necessity of STEM knowledge.

To be coupled with this application-oriented, problem-solving and group-learning scenario within STEM education, it has also been shown that the social relevance of a career path should be highlighted to second level students. As such, medically-associated applications may be considered to have good potential as a focal-point for student PBL. Many medical initiatives require in-depth clinical testing, alongside extended periods of application before results may be seen. But it is important that students are presented with the ability to witness the implementation and resulting effects of their endeavour within the scope of their second level education, so that the effect of their personal involvement in a project may be made apparent.

6. MEDICAL NEED

Cerebral Palsy (CP) – loosely translated as 'brain paralysis'– is used as an umbrella term to refer to a range of congenital neurological disorders, resulting from aberrations in the brain development during pregnancy. While research is still on-going, and in some cases the CP causes are unidentifiable, abnormalities often occur as foetal defects or injury during premature birth. During developmental years (0-3), children may also develop CP due to toxins, drowning (hypoxia), or choking (asphyxia) – through inadequate oxygenation of areas of the still-developing brain.

CP in infants may not be detected up to the age of three years, but commonly manifests in the form of varying degrees of hemiparesis – a difficulty in muscular control. While hemiparesis can be considered less severe than spastic hemiplegia, a common neuromuscular effect of CP in which one half of the patient's body is debilitated under a constant state of muscle-contraction, hemiparetic cerebral palsy (HCP) sufferers encounter difficulties such as a lack of muscle coordination and problems with fine motor control. Related sensory-based difficulties are also reported, with CP sufferers showing difficulty in perceptual problems such as hand-eye coordination and depth-perception. Widely varying levels of muscular function are reported by both sufferers of spastic hemiplegia and hemiparesis – from difficulties with activities of daily living (ADLs) to complete limb paralysis.

While the condition of CP is as a result of early-term, permanent damage to the cerebrum, and is termed as non-progressive in nature, it is common for sufferers to encounter a worsening of the condition due to impeded or avoided use of the affected limbs – whether or not this is conscious on the part of the patient. As such, occupational therapies (OTs) such as Constraint-Induced Movement Therapy (CIMT) have been developed, wherein a patient is required to use the impeded limb for extensive periods of time – by means of constraints applied to their "high-functioning" limb – during their ADLs or specially-assigned therapeutic tasks.

Due to the sporadic nature of the muscular impedance and the involuntary, jerking movements often characteristic of the HCP-sufferer, long-term patient motivation with regards to OT is difficult to maintain – especially in cases of younger sufferers. With nearly 1 in 400 students within the standard education system across Ireland currently suffering with some degree of CP, it is clear there is a need for technological innovation in the region of robotic rehabilitation for fine motor control difficulty.

7. CONCEPT DETAIL

The underlying theory behind the *'RebRob'* concept is to combine a strong example of the social importance of engineering – the reliance of the medical field on technological innovation – with an accessible class-project to which students may personally relate. It is therefore designed to encompass the participation of a group of school students, as well as a young person of similar age undergoing occupational therapy (OT) in the form of fine motor control improvement for mobility-impaired cerebral palsy (HCP).

Upon commencing the RebRob module, students are provided with a robotics set, webcam, and obstacle course appropriate to the size of the robotics. The task presented to the students is the construction of a robot capable of navigating the obstacle course through a combination of remotely controlled motors and sensors – thus requiring the students to both learn and utilise a wide range of STEM theory taken directly from second level curricula. During the introductory section of each class module, students may be exposed to scientific concepts in a transmittal manner, but this accumulated theory is then reinforced with a group-based task during which the students are expected to implement the knowledge they have just acquired using the robotics set.

For example; as part of the second level physics syllabus, students are taught the principles of light, waveforms, and the colour spectrum. Within the RebRob framework, students are then presented with a robotics set, including a light sensor, and required to create a robot which will "follow" a red line. The students must use the theoretical knowledge they have acquired from the subject of waveform recognition and light frequency in order to construct and program a wheeled robot which can tell the difference between colour waveforms received from the light sensor – therefore utilising the information to which they are being exposed.

The young person undergoing OT is then introduced to the classroom of second level students – with bilateral communication enabled through a webcam/microphone setup displaying face-to-face scenes of both class group and patient. Incorporated within the obstacle course are additional webcams, designed to display to the patient both a first-person view from the robot itself, and a top-down overview of the robot's progression through the course. The OT patient is provided with a device, through which they are given control of the developed robot via **IP**.

Due to the nature of HCP, activities of daily living (ADLs) such as tying shoelaces or buttoning a shirt become difficult due to an impedance of the sufferer's fine motor control. In the case of RebRob, the patient is required to use a joystick device to guide the robot through a series of obstacles and interactive sensor-points. The objective presented to the patient requires the same coordination of small muscle movements as needed for these ADLs. The level of skill in joystick manipulation required for the completion of these tasks may be varied and incorporated into the design of the obstacle course – according to the needs of the patient. Further to this, accustomed class groups can be presented with the task of obstacle course design – allowing for a continuously innovative environment which develops in difficulty alongside the skill level of the patient. Patients may also compete with each other or with students through gaming structures such as 'time-to-completion' or 'interactive obstacles'. Thus, the patient is engaging in OT improving their fine motor control, through the act of completing a perceived "game".

For the patient.

- There is a significant increase in motivation. OT is conducted in a highly social environment, where patients may see and converse with peers for encouragement and enhancement of the competitive aspect. [**reference papers on attitude/social influence on patient recovery]**
- The environment in which they complete their OT is continuously evolving, with accomplished class groups turning to the development of obstacle courses with an increased level of difficulty, or with new sensors introduced. In addition to the social motivation, this reduces the possibility of boredom dissuading an OT patient.

For the students.

Through the implementation of the 'RebRob' module, students are not only provided with the STEM theory required by the scope of their second level course curricula, but also with an opportunity to utilise this theory – improving not only long-term information recall, but motivation to further their STEM education. Awareness of what is involved in the engineering field – factors such as teamwork and problem solving – is also improved within the student cohort, through the construction phase of the robotic device. Finally, the social relevance of engineering is strongly underlined through the students' interaction with the OT patient. Students are provided an opportunity not only to witness the social motivation provided through remote bilateral communication, but also the improvement of the patient's ability in fine motor control and coordination – in direct response to the students' efforts in robotic course design.

8. FUTURE WORK

There is extensive scope for expansion and evolution of the RebRob module in both an educational and medical context. There is room for a wide range of research in the realm of devices which may be used in conjunction with the obstacle course. While the RebRob module focuses primarily on the field of fine motor control, haptic devices may be introduced – allowing for the program to address a wide range of conditions, such as chemotherapy-induced peripheral neuropathy and muscular degeneration.

In order to function to efficiently over time, the educational branch of the RebRob module must be seen as a continuously evolving entity alongside STEM curricula and student perceptions. Previously the scope of educational outreach and promotion of the field of engineering within Ireland would have primarily hinged on the civil and structural fields, whereas currently it is areas such as mechanical and manufacturing which are utilised to attract potential third level students. Similarly, through the 1990s employability, rather than social responsibility, would have been a primary factor of consideration for second level students when deciding upon third level study. Identification of the elements influencing students' perceptions of the field of engineering is an undertaking which should be designed to evolve with continuous changes in economic and cultural scenarios.

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