

# Careers-Outreach Programmes for Children: Lessons for Perceptions of Engineering and Manufacturing

Niall J. English, Sylvia Leatham, Maria Isabel Meza Silva, Denis P. Dowling

**Abstract**—The training and education of under- and post-graduate students can be promoted by more active learning especially in engineering, overcoming more passive and vicarious experiences and approaches in their documented effectiveness. However, the possibility of outreach to young pupils and school-children in primary and secondary schools is a lesser explored area in terms of Education and Public Engagement (EPE) efforts – as relates to feedback and influence on shaping 3rd-level engineering training and education. Therefore, the outreach and school-visit agenda constitutes an interesting avenue to observe how active learning, careers stimulus and EPE efforts for young children and teenagers can teach the university sector, to improve future engineering-teaching standards and enhance both quality and capabilities of practice. This intervention involved careers-outreach efforts to lead to statistical determinations of motivations towards engineering, manufacturing and training. The aim was to gauge to what extent this intervention would lead to an increased careers awareness in engineering, using the method of the schools-visits programme as the means for so doing. It was found that this led to an increase in engagement by school pupils with engineering as a career option and a greater awareness of the importance of manufacturing.

**Keywords**—Outreach, education and public engagement, careers, peer interactions.

## I. INTRODUCTION

THE advancement of understanding through training for all age groups, from children to undergraduates, can often be facilitated by both peer interactions and doing demanding projects. The training and education of under- and post-graduate students can be promoted by more active learning [1], and using such approaches as “flipping” the teaching experience [2]. Indeed, comparisons and critiques vis-à-vis active versus passive learning are very informative, in that active learning has been shown, with statistical evidence, to lead to more robust levels of more deep understanding and performance, as well as general critical awareness [3]. Perhaps nowhere is this conclusion more compelling than in fields of engineering education and training [4], where overcoming more passive and vicarious experiences and approaches have been documented in various case studies for their effectiveness. An excellent exponent of this active-learning approach “in action” relates to the application of Problem-Based Learning (PBL) pedagogical approaches, as opposed to a more traditional lecture-and-tutorial method (with the odd laboratory practical session), which has led to improved understanding and usage of key learning outcomes in

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engineering courses [5]. Indeed, reflecting in general terms on engineering-education EPE/ outreach work *per se*, it has been demonstrated to lead to several tangible benefits and improved outcomes [6], such as, *inter alia*, greater engagement and interest with science/ engineering for school-children, careers awareness, enabling teachers with strong contributions to technical knowledge of subjects. More specifically, in the case of engineering outreach [7], it provides development of general professional skills for engineering, e.g., communication and teamwork, where PBL is often an effective tool to enhance outreach.

Despite the exciting and rather commendable progress in recent years of active learning - and PBL as a particular style and embodiment thereof - the possibility of embedding PBL and active learning in the context of outreach to young pupils and school-children in primary and secondary schools is a lesser explored area. Indeed, this type of PBL and active learning in the school context is often termed a type of activity in terms of EPE. Beyond that, exploring what type of “feedback” there may be on shaping third-level education and training, by way of influence on shaping curricula and active-learning styles, is more relatively unexplored still.

In any event, bearing this relative lacuna in the literature in mind, the outreach and school-visit agenda constitutes an interesting avenue to observe how active learning, careers stimulus, and EPE efforts in general for young children and teenagers can teach the university sector, to improve future engineering-teaching standards and enhance both quality and capabilities of practice.

The present contribution involves careers-outreach efforts to lead to statistical determinations of motivations towards engineering education and training, which, in turn, aids in the redesign of engineering curricula for more active learning. Taken together, this initiative offers potential lessons and conclusions for improving perceptions and reality of presenting engineering and manufacturing careers.

## II. CAREER DEVELOPMENT AND PBL IN SECONDARY SCHOOLS

### A. Summary

Turning to the value and benefits of outreach in prompting active-learning, PBL and career-focussed thinking and engagement in teenagers at secondary schools, we describe the ‘Shaping Your Future’ (SYF) initiative, which was a year-long joint pilot project run in Ireland in 2019. It was run by I-Form, the Science Foundation Ireland (SFI) Research Centre for Advanced Manufacturing, in partnership with IMR (Irish Manufacturing Research) – and offered primary- and second-level students and teachers a hands-on experience with 3D-

printing approaches [8]. Pupils were provided with a social problem: devise and 3D-print a piece of equipment to assist a disabled individual or to convey disaster-relief support. The outcomes of the scheme demonstrated that pupils garnered an enhanced comprehension of advanced fabrication and regard these professions as a vehicle by which challenges can be tackled and, overall, the quality of life to be ameliorated, in a broad sense. The active, hands-on aspect of the programme was the most valued aspect (*vide infra*), and teachers maintained broadly that the provision of a piece of infrastructure was a key motivator for taking part in the programme. This project was funded through SFI's Discover programme.

### B. Rationale and Context

According to SFI's "Science-in-Ireland Barometer" [9], the intangible and seemingly distant nature of science and technology can make it difficult for the public to appreciate. This, in turn, can lead to poor uptake of Science, Technology, Engineering and Mathematics (STEM) subjects in schools.

The 'Shaping Your Future' project offered a chance for primary and second-level students and teachers to obtain hands-on experience in 3D-printing technology, and thus gain an appreciation for its excitement and potential.

Participants experienced what it means to design and create using 3D-printing technology, with the guidance and support of manufacturing researchers from the local community in Ireland's Midlands. The intention was to inspire the next generation to consider high-skilled STEM careers, and to broaden teachers' views of the potential (near-term) career possibilities. Those involved in this scheme originated from a broad suite of previous experience, emphasising the imperative for manufacturing to diversify in terms of personnel. The scheme comprised two components – one for pupils and the other for teachers.

For the intensive, Transition-Year (second level, 15-16 year olds) part of the programme, four schools were selected, based on three factors: geography, current school engagement with STEM, and type of school, ensuring a mixed socio-economic status within the target population. Another important factor for selection was the school's current status with regard to STEM subjects. Locations in areas of low STEM-subject activity (as identified in previous SFI-Discover reports) were prioritised for engagement.

We selected two all-girls schools and two mixed-gender DEIS schools; 'DEIS' status is an official indicator of a school facing socioeconomic challenges. All four schools are in the Midlands of Ireland. The girls' schools have a self-described poor track record in STEM engagement, with many technical subjects not on offer at the schools (e.g., technical drawing, engineering, technology). For the primary-level programme (for children aged 8 to 10), two local schools were engaged (*vide infra*).

In terms of the teacher-engagement element of the programme, teachers from the national Engineering and Technology Teachers Association (ETTA) participated in a day of 3D-printing training.

### C. Outputs

- 104 primary-school students each had an interactive visit to IMR, featuring a design-thinking workshop, and interactions with researchers working in virtual reality, robotics and 3D-printing. In-person sessions were provided a month or so later, whereat pupils familiarised themselves more thoroughly with 3D-printing/design using Tinkercad software.
- 14 Engineering and Technology teachers travelled from across the country to University College Dublin (UCD) to take part in a day-long workshop on how to bring 3D-printing into the classroom. They learned from I-Form how haptic gloves are resulting in better degrees of control on operations, and how this can interface productively with virtual-reality platforms.

I-Form then linked the instructors with global 3D-printing equipment provider GE Additive in the USA, who run a global 3D-printer-donation scheme for schools. 10 teachers were supported in submitting applications (7 had attended the training day above; 3 were taking part in our Transition-Year programme). All 10 were successful in their application for a free Dremel 3D printer for their school.

- For the teenage cohort (aged 15 to 16), this scheme started in Autumn 2019, ending in a final near Christmas 2019. The four schools (as described above), featuring about one-hundred pupils, were provided a demanding task from the supervising group: in groups of four or five, to prepare an innovative object which would help a person with a disability, or would be of humanitarian aid in a disaster zone. Each school received 5 'interventions': 2 visits by researchers to the classroom, 2 sessions at IMR, and a trip to an industrial venue.

At school, pupils were advised to undergo a 'design philosophy' way of thinking in relation to the social problem at hand, and subsequently to describe and promote their thinking to the team, who provided advice and support, often iteratively, during the process. Throughout an initial stint at IMR, pupils advanced their understanding of Tinkercad and virtual reality. Pupils were in competition to get to the last round, whereat they summarised and promoted their work to a Board of Assessors.

The overall winner was called 'Keyzy' – a 3D-printed key aid inspired by a student's grandmother who suffered from tremors due to Parkinson's disease.

### D. Outputs and Evaluation

A mixed-methods approach was carried out to evaluate the Transition-Year element of the programme, incorporating teacher, student and researcher feedback, and entailed qualitative teacher interviews (by 'phone) before and after the programme, a teacher focus group, student attitude surveys (before and after), and a researcher survey (before and after).

The target outcomes of the programme for students and teachers were to:

- Understand how 3D printing works, and how it is changing how things are made.
- Understand how manufacturing is changing, and some of

what the next industrial revolution entails ('Industry 4.0').

- Relate to local engineers and researchers and understand what they do.
- Learn that science and STEM subjects are the key to unlocking exciting jobs of the future.
- Learn that engineering is an exciting, creative, innovative, high-skilled job, where people work in teams to solve problems together.

### E. Statistical Findings

In terms of perceptions of manufacturing before and after the programme, there was an increased sense of how complicated this is, and that there are many new things and approaches to learn (cf. Fig. 1). Indeed, this sense of how richly complicated manufacturing and engineering really is was reinforced by an increase in interest in an engineering career after the programme, in Fig. 2

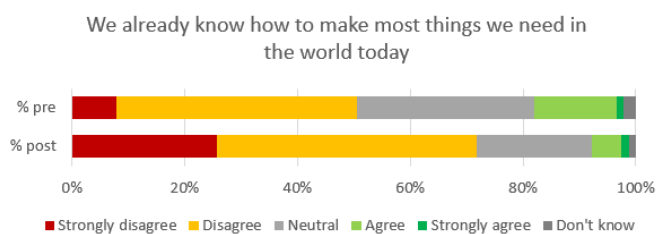


Fig. 1 Perceptions of certainty of manufacturing's nature before and after the programme

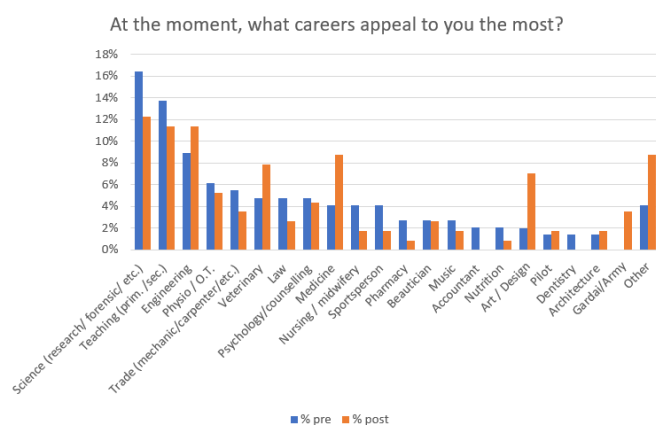


Fig. 2 Shift in career intentions before and after the programme

In terms of enjoyment and interest in the programme *per se* by pupils, there was a strong appreciation of the specifics of learning about manufacturing and 3D-printing, as well as learning more about career options and teamwork (cf. Fig. 3). This overlapped with the expressed goals of the programme, implying that there was a good degree of success.

In the case of teachers, the mean score of appreciation of support from the programme was 7.5/10, with 8.7/10 for the nature of the organisation itself.

### III. KEY FINDINGS AND LESSONS

In terms of the primary-school outreach and PBL by hydrate cages, interviews with teachers emphasised that the

key point of feedback was that the engaging, playful and theatrical style of the interactive lesson was key. It was also noted by them that the tactile nature of the competitive group play and teamwork for the young children with magnets was the most important way of copper-fastening their interest, given that young children learn so much through play [9].

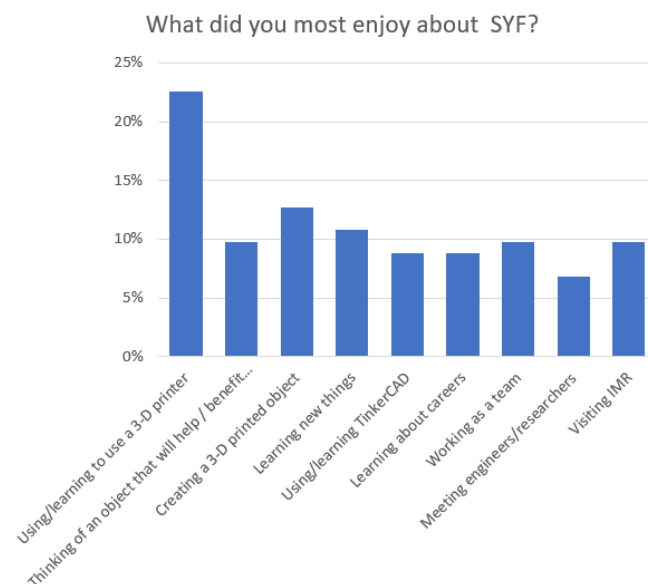


Fig. 3 Aspects of the programme which were most enjoyed by pupils

In the case of the 'Shaping Your Future' initiative, the main findings and recommendations are summarised here. Further details are provided below.

- Students exhibited an increased understanding of engineering.
- More students were able to recognise and identify engineers after the programme.
- There was a significant increase in agreement with the statement: 'Engineers are very important to society'.
- Students' perception of manufacturing as an industry was changed positively.
- In terms of career interests, there was an increase of interest in engineering. However, when split by gender, some small changes were notable, with girls slightly more interested after the programme and connecting well to the societal-impact "messaging".
- Students enjoyed the hands-on aspects of the programme the most; twice as many female students as male enjoyed this aspect. Twice as many girls enjoyed creating a 3D printed object, while three times as many girls enjoyed learning about careers.
- The inclusion of a piece of infrastructure (3D printer) was expressed by most teachers as the strongest selling point for participation in the programme.
- All teachers maintained that the programme provides a template to run it in future years.
- A motivating factor for the girls' schools engaging positively with the programme is the lack of technological subjects on offer in the school.

- Teachers viewed the hands-on, tangible nature of the programme as most valued.
- Many found that the students took the lead - even teaching other students how to use the software.
- Teachers reported a 'surprising' level of interest from girls, but that some boys were less interested than expected.

In more detail:

- Students exhibited an increased understanding of engineering. In response to the question, 'What does an engineer do?' there was a significant drop in the perception of engineering as involving engines and machines, with only 2 people giving this response after the programme, compared to 14 before the programme.

After the programme, there was a significant increase in the numbers of those who viewed engineering as solving problems/improving lives, with an increase from 17 to 27 people giving this response. There were also increases in the number who identified engineering as involving designing or making. This shows that the programme has helped to "reframe" students' views of engineering, from a narrow focus to a broader view, with strong elements of problem-solving and helping people.

- There was a significant increase in agreement with the following statement: 'Engineers are very important to society', with an increase by 24 percentage points in those 'strongly agreeing'. Similarly, the statement 'Engineers will be less important in the future' saw a significant growth in those disagreeing and strongly disagreeing, with a total of 78% in these two categories after the programme.
- Students' perception of manufacturing as an industry was positively changed. Students displayed a better understanding of the manufacturing-jobs landscape in Ireland at the end of 'Shaping Your Future', with 31% disagreeing or strongly disagreeing with the statement 'There aren't many manufacturing jobs in Ireland right now', compared with 22% before the programme, and a reduction in those saying 'Don't know' from 47% to 36%. In addition, after the programme, far more people (10% points change) disagreed strongly with the statement: 'Manufacturing mainly makes things I don't really need', and there was a marked increase in disagreement with the statement 'We already know how to make most things we need in the world today'.
- When asked directly 'Would you like to work in engineering or manufacturing?' there was a slight increase in interest vis-à-vis before and after the programme. After the programme, there was a small reduction (-5 percentage points) in the number of girls who answered 'No' to the above question, and a small increase in the number of boys who answered 'No'.

A large number (23) of girls chose not to answer this question, however, leaving it blank in the final survey.

We need to explore the possibility that boys were slightly dissuaded by the perception of engineering and manufacturing as being a tool for helping people, just as girls found this

aspect appealing. Teachers reported that girls connected well to messaging around societal impact, whereas boys did not seem to care so much. This finding is supported by the fact that gender balance is much better on biomedical-engineering degree courses compared to other types of engineering.

- Students enjoyed the hands-on aspects of the programme the most.

Four teachers were interviewed at length before and after the programme, and took part in a focus-group discussion after the programme. The main findings were:

- The inclusion of a piece of infrastructure (3D printer) was expressed by most teachers as the strongest selling point for participation in the programme.
- All teachers said the programme provides a template to run it in future years. They all plan to be involved long term. Some teachers are now working across disciplines with other teachers to use 3D printing for, e.g., mathematics, biology.
- Teachers see this project as helping their own career progression, and plan to make it their own over the years. They are keen to learn new skills and invest in personal growth.
- A motivating factor for the girls' schools is the lack of technological subjects on offer in the school. Schools are keen to keep up with local competitors. They see the programme as prestigious for their school. School management saw the benefits of participation in the programme.
- Timing was an issue, in that some underestimated how much time they would need to participate. Also, gaining access to computers was also an issue in some schools. Teachers would have liked more guidance and training at the outset, and more availability of technical support throughout the programme, preferably in person.
- The hands-on, tangible nature of the programme was most valued. Students took pride in producing their own objects.
- Teachers reported a 'surprising' level of interest from girls, and that some boys were less interested than expected.
- Teachers would like future themes to be more relevant to students' lives.

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