Engineering and Society: Embedding Active Service Learning in Undergraduate Curricula

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KEYWORDS: Public Engagement, Outreach, Engineering Education, Science Education, Primary Teaching

SUMMARY

Undergraduate education incorporating active learning through education outreach presents a critical opportunity to influence future engineering teaching and practice capabilities. Engineering education outreach activities have been shown to have multiple benefits; increasing interest and engagement with science and engineering for school children, providing teachers with expert contributions to engineering subject knowledge, and developing professional generic skills for engineers such as communication and teamwork. A new module at the University of the West of England, Bristol (UWE), called Engineering and Society, paired 45 student engineers and 32 pre-service teachers to enact engineering outreach in primary schools, reaching over 900 children in 30 school classes. A pre and post longitudinal mixed methods design is being employed to measure change in attitudes and Education Outreach Self-Efficacy in student engineers; alongside attitudes, Teaching Engineering Self-Efficacy and Engineering Subject Knowledge Confidence in pre-service teachers. Previous pilot research indicates that highly significant improvements were noted in the pre-service teachers' confidence and self-efficacy; while both the teachers and engineers qualitatively described benefits arising from the paired peer mentor model.

BACKGROUND / CONTEXT

Universities occupy a vital role in the community; thus undergraduate education incorporating active service learning provides opportunities to influence communities now and in the future (Direito et al. 2012). One example is engineering education outreach, where engineers take part in Science, Technology, Engineering and Mathematics (STEM) activities with schools and communities. These activities have been shown to increase children's interest and engagement with science and engineering (Molina-Gaudo et al. 2010; Stapleton et al. 2009) while also providing teachers with expert contributions to engineering and scientific subject knowledge (Laursen et al. 2007).

Attitudes at primary school in particular can influence later interest in STEM, especially for girls who develop their gender identity and consequently the appropriateness of STEM as a career before entering secondary school (Archer et al. 2013). This is

important for future STEM progression, as the way science is taught in primary and secondary schools has been identified as a contributing factor in the declining interest in STEM subjects at Higher Education level, which is critical for continuation into many STEM careers (EngineeringUK 2017). An inquiry-led, active learning approach can motivate learners and help them to achieve many of the end goals of science education (Madhuria et al. 2012). However, in order for such an approach to be successful, teachers need not only to have robust levels of subject knowledge but to also have confidence in their subject knowledge (Chue & Lee 2013). This highlights the importance of addressing and positively influencing pre-service teachers by cultivating positive dispositions and beliefs towards subjects such as science and engineering during their training, through opportunities to reflect on experience and practice in schools (Jung & Rhodes 2008; Flores & Day 2006).
Service learning through education outreach has also been found to benefit engineers themselves, enabling the development of generic skills such as communication and teamwork, required in professional environments (Direito et al. 2012; Pickering et al. 2004). In previous research, the authors demonstrated that positioning student engineers as 'experts' enables active learning, encouraging the consolidation and communication of engineering concepts to wider audiences such as children and teachers (Fogg-Rogers et al. 2016). Alongside this, working with the community enhances the employability of student engineers (Duffy et al. 2008), whilst also working towards professional codes such as the UK Standard for Professional Engineering Competence (UK-SPEC) or professional status awards such as Chartership.

AIM AND OBJECTIVES

This project aimed to develop a new model of undergraduate education, integrating active learning through paired peer mentoring. Student engineers were paired with pre-service teachers to co-mentor each other to deliver hands-on inquiry-led science education to primary school children. The project objectives were to:

- Enable collaboration between staff from three interdisciplinary departments at UWE Bristol, alongside working with local schools, Education Continuing Professional Development (CPD) organisations, Informal Science Learning providers, and regional Engineering Industry and Professional Bodies.
- Enhance student employability by responding to demands from industry for ready and able graduates with: student engineers developing public engagement and generic skills for Professional Chartered Status; pre-service teachers developing Science, Technology, Engineering and Mathematics (STEM) subject knowledge and teaching confidence; and primary school children developing interest, enjoyment and positive attitudes to STEM subjects.
- Enrich primary school STEM capacity and provision by providing CPD for professional engineers undertaking outreach within the West of England region, taking account of gender and Black and Minority Ethnic role modelling and mentoring.

- Develop an undergraduate degree credit model which can be utilised within student degrees across the UK, meeting the needs for Engineering and Education professional body accreditation.

RATIONALE

This project builds on pilot work undertaken from 2014-2016. The Children as Engineers report (Fogg-Rogers et al. 2015), and international peer-reviewed journal article (Fogg-Rogers et al. 2016) indicate that these small-scale models had significant benefits for volunteer participants, with student engineers gaining public engagement and other generic skills (important for Professional Chartered Recognition). The pre-service teachers showed highly significant improvements in STEM subject knowledge and teaching confidence/self-efficacy which is important for meaningful education outcomes in STEM subjects in primary schools, and the professional teachers reported being inspired to adopt a STEM approach to teaching. The children enjoyed the inquiry-led science education with expert engineers, which is important for developing children's aspiration and enthusiasm, especially girls, for future STEM subjects GCSE choices.

This project seeks to extend and evaluate this work into a sustainable degree-wide optional credit-bearing model for higher education students, which would enable it to be rolled out annually across UWE and nationally into other universities.

METHODOLOGICAL APPROACH

Students (N=45) from engineering degrees at UWE have taken the newly developed 'Engineering and Society' module in 2017. The module has been designed to enhance engineers' communication skills and provide them with the evidence needed to complete the UK SPEC for Engineering Technicians. The engineering students are being assessed on their portfolio of evidence-based practice as well as a presentation of their learning about public engagement and engineering in society.
The engineering students were paired with 32 pre-service teachers taking an Initial Teacher Education degree. Training for the engineers was provided in public engagement, STEM and society, and inquiry-led science education, while training for the teachers was provided in the engineering design process and related STEM concepts. The paired students mentored each other to co-develop and deliver outreach interventions for local classes of primary school children. Ten primary schools took part in the project, reaching 900 children in 30 classes.

A pre and post longitudinal mixed methods design has been employed to measure changes in attitudes and Education Outreach Self-Efficacy in student engineers. The pre-service teachers were assessed for changes in their attitudes, Teaching Engineering Self-Efficacy and Engineering and Science Subject Knowledge Confidence. Impacts on the children are also evaluated.

DISCUSSION

This new embedded model of service learning aims to provide real-world experience and opportunities for engineers and teachers. Engineers are being urged to undertake more public engagement in order to enhance perceptions of STEM careers (EngineeringUK 2017), and teachers are a very influential audience to work with. Indeed, research indicates that teacher professional development benefits the teachers, their school children, and the schools, and changes teachers' attitudes towards their teaching (Woolhouse & Cochrane 2009).

Peer coaching, such as that used within this project, may be useful for other engineering education courses, as it discourages practitioners from working in isolation and instead encourages active learning discussions (Van Driel et al. 2001). Engineering education outreach focussing on mentoring pre-service teachers is therefore valuable for engineers to influence societal attitudes and attainment in STEM, alongside improving their own generic skills for career development.

A toolkit from the pilot project (Fogg-Rogers et al. 2016) is available online (http://eprints.uwe.ac.uk/26053/7/Web%20-%20UWE%202015%20Children%20as%20Engineers%20Paired%20Peer%20Mentors%20Final%20Report%20web%20version.pdf), and further updates will be provided on the Science Communication Unit blog (https://uwescicomm.wordpress.com/2017/09/11/engineering-in-society-new-module-for-engineering-citizenship/

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