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# FORMATION OF AN ENGINEERING IDENTITY: INDUSTRY ROLE MODELS & PROBLEM BASED LEARNING

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**Abstract:**
In vocational disciplines such as engineering, industrialists can provide students with access to real-life projects and artefacts that expose them to practice knowledge and employability skills. Assistance from Alumni role models can help students to imagine and reflect on their future self as graduate engineers. In this paper, two initiatives that aid the students' transition from 'novice to becoming' civil engineering graduates are examined. (1) Graduate mentoring of student mentees during their third-year of studies and (2) a hybrid problem/ project-based series of workshops know as Civil Engineering 4 Real (CE4R). Both initiatives fostered a collaborative academic-industry partnership whereby undergraduates were introduced to an engineering practitioner community of practice. Both initiatives have exposed students to the breadth of civil engineering practice and sub-disciplines within the profession. Whilst the feedback from the students is overwhelmingly positive, there is a need to ensure both initiatives are considered with respect to the wider course curriculum.

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## 1. INTRODUCTION

The provision of an authentic curriculum that contextualises learning and assists students to develop a professional identity, aligned to the generic skills and competences required by the professions, is now considered to be an essential remit of higher education ( Lowden et al., 2011; Pegg et al., 2012). Indeed, the University of Strathclyde seeks to 'ensure that all of our students are able to develop work-related competencies that will increase their work-readiness and enhance their future careers' (UOS, 2018). A number of reports examining the engineering sector (Lucas et al., 2014; Broadbent and McCann, 2016) have argued that these professional skills are best nurtured through closer industry-academia collaboration. For civil engineering courses 'there should be strong, viable and visible links between departments and the profession [and] local practising engineers should become involved with the education of students' (Joint Board of Moderators, 2017, p.30). This idea is not novel given that past civil engineering scholars spoke of students attending 'special evening lectures, by men who have had large experience in one branch of engineering' (Dyer, 1880, p.17) and the provision of talks for students so that they have an 'opportunity to converse with men of mature practical experience' (Inglis, 1941, p.11). The two industry-academia initiatives showcased in this paper have

surpassed the JBM requirements through offering the students an exploration of the various sub-disciplines within the civil engineering sector (Mills, 2011). Table 1 provides an overview.

|  | Mentoring 2010-2018 | CE4R 2012-2018 |
|---|---|---|
| Number of Employers Participating | 49 | 45 |
| Number of Civil Engineer Employees | 139 | 132 |
| Number of Students | 621 | 357 |
| Number of Student attendances | 4 visits per group | 1596 |
| CPD hours Created | Circa 5000 | 3192 |

**Table 1: Mentoring & CE4R Statistics**

## 2. RESEARCH METHODOLOGY

The selection of a research methodology should be aligned to the aims and objectives of the research question. In this case, both initiatives were introduced to fill a perceived gap in opportunities for the students to learn alongside practising engineers. The void is particularly noticeable in a shortfall of disciplinary summer placements that allow students to road-test their theoretical knowledge (Tennant et al., 2018). Whilst both initiatives can be considered pedagogical interventions, they were not planned and enacted through an Action Research (AR) structure and were not therefore subject to a deliberate and focussed investigation at the time. On being reflexive, it is clear that the scholarship of both initiatives could have been professionalised through the lens of an AR project (discussed further in conclusion). As such, the corpus of data available from these initiatives was initially intended only to provide an outlet for students to be reflective about their learning and practice (an assessed report on their mentoring experience) and to provide feedback to guest engineers offering a CE4R workshop (a short Likert questionnaire including free-text questions).

Given that both initiatives encourage peer learning in groups – with aided scaffolding from practicing engineers – it is appropriate to evaluate them through a social constructivist lens. Due to the mentoring programme starting in 2010, the data corpus is saturated with text from 621 student reports (circa 2500 word each). An earlier cursory coding and thematic analysis provided a number of salient themes that have remained dominant in subsequent years. The CE4R quantitative data has also been tallied, and the free-text subject to a cursory coding and thematic analysis (see Braun & Clarke, 2006). An inductive, in vivo coding technique was employed searching for a 'word or short phrase taken from that section of the data' (King, 2008, p.473) that conveyed the students' perspective. Furthermore, in adopting the TA approach, we were able to logically condense the vast data corpus into meaningful themes, according to frequently arising patterns within the discourse (Braun & Clarke, 2006).

## 3. MENTORING UNDERGRADUATE CIVIL ENGINEERS

Established in 2010, the main objectives of the mentoring initiative were to expose third-year students to authentic civil engineering practice. Fundamental to this was their exposure to real projects and multidisciplinary teams (Murray et al., 2015) in-situ. In groups of four, the students visited their mentors in the field, at a consultant's office, and/or to a live construction site on three/four occasions. This provided the mentees with a high level of realism that assisted 'the construction company looking to its long-term recruitment needs, the HEI needing to fulfil its JBM accreditation requirements, and the students who are looking to fulfil their career

aspirations' (JBM, 2017, p.20). To date, 621 student mentees have benefited from the input of 45 employers and 135 mentors. This has resulted in circa 5000 hours of students Continuing Professional Development (CPD).

Typically, the mentors (often Alumni) would also provide mentees with access to their peers who would shed light on their own graduate trajectories, describing the various sub-disciplines involved in civil engineering work. Topics for subsequent meetings would be dependent on the business sector in which the mentor works, but would include design information, commercial awareness, risk etc. The department's industrial advisory board published guidance to assist the mentors. As an assessment task – and to encourage students to reflect upon their mentoring experience – they were required to submit a report (40% weighting of a 10 credit Construction Project Management module) that would demonstrate an awareness of their transition through their Personal Development Planning (PDP)-CPD –Initial Professional Development (IPD).

3.1 Results
The verbatim extracts that follow suggest the mentees awakened to the possibilities of a purposeful and interesting career that they had perhaps envisaged, but lost sight of during exposure to a traditional higher education pedagogy *("*there was a lot to learn from being mentored by someone from the industry. Experiencing things such as this first hand is irreplaceable and no exam or PowerPoint presentation can have an even remotely similar *impact")*. Reflections such as this corroborate the quantitative data with 86% of the mentees agreeing/strongly agreeing that the mentoring experience had been inspirational.

It was evident that mentees had begun a transition towards becoming independent learners with metacognition skills ("the mentoring experience opened my life to a new way of learning*")*. For many mentees, the mentoring acted as a catalyst for renewed interest in their studies ("for a while I felt like I was just coasting through the course but this has reinvigorated my *enthusiasm")* and as confirmation that they had selected the appropriate degree ("I had thought for a while that civil engineering might not be for me. This experience proved otherwise, I was motivated and my interest in becoming a ci*vil engineer increased suddenly")*. In this regard, 86% of the mentees agreed/strongly agreed that the mentoring experience had helped confirm their intentions to become a civil engineer upon graduating.

For some students, the physical setting of the mentor's office provided an opportunity to envisage life beyond university ("the moment I sat down, I took a look around the room and imagined myself working as a civil engineer already*")*. Whilst simulating such authentic social experiences through a replication of a professional "design office" (JBM, 2017, p.6) within universities is encouraged, it cannot replicate the nuanced cultural climate and interpersonal chemistry that comes through exposure to real engineering practice in-situ. Exposure to these workplaces found 77% of the mentees agreeing/strongly agreeing that they would like an opportunity to work for their mentors' employer on graduation. Whilst this may be due to euphoria/fears about securing graduate employment, the mentees could sense when their mentors had been paternalistic, with 91% of the mentees agreeing/strongly agreeing that they would recommend their mentor for subsequent student cohorts ("T*he company was very*…keen to have us there, as were all the *friendly*…staff we met during our visits. From our first m*eeting*…it was clear that he was treating th*is as a proper mentoring scheme*…he wanted us all to benefit from *the experience")*. Such positive role models are reflected in the mentees' desires to become

mentors themselves, with a 76% agreeing/strongly agreeing rate. Given the first cohort of mentees graduated with BEng (Hons) in 2012/MEng in 2013, the initiative is now self-priming with the majority of mentors being Alumni.

Upon reflecting on their university studies post-mentoring, there were mixed views as to how industry relevant they considered university learning to be ("These graduate engineers gave me a far deeper account of the industry than most of my lecturers and I believe I learned more from them than most of $1^{st}$ and $2^{nd}$ year lecturers combined"). However, 63% of the mentees agreed/strongly agreed that their academic studies would help them prepare for a career in civil engineering. Given that one aim of the mentoring experience was to provide students with real industry examples of design and technological work, it is no surprise that 80% of the mentees agreed/strongly agreed that this had been achieved ("we were shown around the new endoscopy extension. This was quite exciting in witnessing the construction of a building. Most of the elements of the buildings I could identify like pre-cast concrete floor slabs, bridge beams etc."). Some mentees were able to draw on specific knowledge from individual modules ("I was initially concerned to discover my placement was within a sewage site as I thought my interests were more towards structural engineering than water engineering, however, I realised that the upgrade works related well to topics within our *environmental engineering class*" thereby affording us a good opportuni*ty to relate theory to practice*").

In regard to the longer-term impact of the mentoring, 87% of mentees agreed/strongly agreed that on return to their fourth-year of studies, they would become more engaged with their PDP. Whilst anecdotal evidence would suggest this was a 'fanciful' self-fulfilling prophecy for some mentees, others used the mentoring as springboard to capitalise on prior knowledge and skills through an explicit awareness of how undertaking CPD during university studies would feed into their IPD as a graduate engineer *("It has helped me realise that we must continue to learn outside university not just when I leave but also during our course")*

## 4. CIVIL ENGINEERING FOR REAL (CE4R)

CE4R was conceived when the lead author experienced an early morning "epiphany" in 2012. An experience perhaps more common to academics than reported given that Tosey (2006, p.30) referred to his own '3 a.m [awakening] to find the metaphor of change as drama in my awareness'. The CE4R metaphor is perhaps the result of the unconscious-subconscious mind linking pedagogy and pleasure. The pleasure of recollecting the music of the Welsh rock band the Manic Street Preachers, but also a disturbing incident in 1991 when one band member self-harmed during an interview with a BBC journalist by cutting the words '4 REAL' into his arm (see Berry, 2015). Thus, whilst it would be convenient to suggest that the pedagogical and pleasure intent behind CE4R was a forerunner to Parkinson's (2017) Being punk in higher education: subcultural strategies for academic practice, no such claim can be made. However, CE4R was intended to be a disruptive pedagogy in that the approach to peer learning across cohorts, and industrial participation was novel. The workshops offered students a hybrid of problem and project-based learning in a co-curricular evening workshop setting.

CE4R provided students with 'real-world experiences' (Anderson et al., 2010, p.171) during evening (5-7pm) workshops that were facilitated by industrialist who furnished the students with an authentic 'industrial flavour that most professorial cannot duplicate' (Wankat and Oreovicz, 2015 p.135). Students who attended were purposefully allocated (as a means to leverage peer

learning) into groups of between 4-5 that provided a mix of cohorts across the five-year MEng course. So as to help the students learn how to solve workplace problems (Jonassen, et al., 2006) the industry guest(s) provide a 20min synopsis of a current or historical project (often with local significance) problem(s) and supply authentic engineering documentation as a means 'to put theory into context' and to help 'students understand what they might be producing and what role they might play' and to 'reinforce the sense of belonging to a community of practitioners (Broadbent and McCann, 2016a p.18). To date, 67 workshops have been delivered by 132 engineers representing 45 employers. A total of 357 students have attended workshops resulting in 1571 student attendances, equivalent to 3142 hours of student CPD.

4.1 Results

The quantitative results from the Likert questionnaires are based on 1477 returned questionnaires from 357 students. Individual student participation at the workshops ranged from one attendance to more regular attendees including one student who attended forty workshops. Thus, the quantitative results are indicative and should be considered as a guide to complement the free-text responses rather than as a deterministic data set.

Given the industrial presenters offered a credible immersion in real work problems, students perceived CE4R to be authentic, and 80% of the returned questionnaires agreed/strongly agreed that the workshops were inspirational ("the chance to be taught by a practising engineer currently working in the industry gives a real edge to the situation; reinforced by the real-life *examples")*. The delivery of the workshop problems can be considered a form of storytelling whereby the case study vignettes offer students a plausible insight into civil engineering ("The workshop run by [the company] provided a more interesting and exciting learning experience than most lectures can offer as well as giving an insight into how a real groundwork investigation would be managed*")*. A number of first-year students were disappointed that they could not contribute prior knowledge to the process ("I personally struggled to read the drawings to the same level of detail as the other members in my group. This made it difficult for me to grasp the concep*t of what was being asked to do")*. However, peer learning did help *("The older students were really good at explaining things to first-*year level"; "Highly complicated for a first-year student but in the end I understood due to my te*ammates")*. Further research is needed – perhaps utilising Vygotsky's Zone of Proximal Development (ZPD) – to explore how students and industrialists provide "scaffolding" to support learners (Harland, 2003).

The nature of interpersonal dynamics within each student group, and whether evidence of teamwork behaviours emerged during the problem-solving activities, offers fertile ground for further research. To date, the Likert questionnaire and free-text data offers a self-reporting perspective in relation to the degree of creative thinking undertaken by individuals and their groups, and the cognitive application of analysis and synthesis attributes. Nonetheless, CE4R fosters a 'learning environment which facilitates collaboration, creative thinking and ingenuity' (JBM, 2017, p.4) whilst helping produce graduates who are 'articulate, imaginative, confident and inquisitive' (JBM, 2017, p.23). The fuzzy nature of the problems presented in the workshops appear to promote a divergent approach, albeit Reisman (2017 p.19) has argued that creative thinking 'is the sequence of divergent-convergent thinking' ("The complexity of the problem was at the right level; easy enough to get to grips with quickly, yet still plenty of scope for creative thinking*"; "A very difficult challenge and we didn't find the correct solution but thinking* through the problem *improved my engineering skills")*. The questionnaires suggest that students

regarded themselves to have engaged in creative thinking, with 83% of agreeing/strongly agreeing responses. 82% of the questionnaires indicated that the students agreed/strongly agreed that they had engaged in analysis, and 81% agreed/strongly agreed that they had engaged in synthesis. Clearly, these figures are open to interpretation and in need of further research to elicit concrete examples of the deployment of such cognition during the problem-solving activities. Ideally, such research would also consider a growing interest in curiosity (Levrini et al., 2017) and imagination (Whitton, 2018) within higher education pedagogy.

The active dimensions of the workshops were contrasted with lectures that perhaps reflect a deductive and passive learning experience ("the workshop made the lecture/learning element fun. I think perhaps more of our actual lectures should *be more interactive like these"; 'this* type of learning is much more enjoyable and interactive"). For some students with prior industrial placements, CE4R was considered as an authentic surrogate to the peer communication experienced in industry ("The discussions I experienced last night between my group weren't too dissimilar to what I had experienced working on a similar project while in the design office. To me this highlighted how well CE4R does in giving students the opportunity to experience what life as a civil engineer will be like after graduating*")*. This perception corresponds with Gavin (2011) who found that final-year civil engineering students exposed to project-based learning considered their team working, design and communication skills to have been improved.

## 5. Discussion

Viewing both initiatives through a constructivist lens, it is argued that a combination of active and authentic learning has piqued the students' interest in their studies and future professional career. Both initiatives required the students to accept ownership of their learning, and to play a prominent role in shaping their professional identity as civil engineers. Students with prior knowledge of industrial practice appeared to be highly motivated to engage with the initiatives, and to help their peers learn. However, other students experienced varying levels of discomfort and self-doubt when exposed to industrial practice. This raises questions about how engineering courses are preparing students to enter employment "running", rather than as "rabbits in the headlights". It may be that other vocational disciplines such as medicine, nursing and dentistry have advanced experience of integrating professions with academia. Nonetheless, unsolicited testimonies from graduates demonstrate that both initiatives provide an opportunity to gain employment capital. Whilst these testimonies may suggest that the students have adopted an instrumental perspective to their education, it should be noted that the authors believe that higher institutions should offer engineering students an appropriate blend of vocational and liberal learning experiences.

## 6. Conclusion

Both the initiatives examined in this paper rely on industrial assistance, and this form of collaboration appears to be firmly established within vocational higher education courses. To mitigate the reliance on industry input, there has also been a call for academics to have relevant industrial exposure (Neves & Hillman, 2016) and the RAE (2018) RAEng Industrial Fellowships are intended to assist academics in gaining industrial capital to enhance teaching and learning. Correspondingly, and perhaps due to the relatively small number of academics (no public figures are available) taking up this opportunity, the RAE (2018) Visiting Professors scheme appears to remain a popular alternative. However the Teaching Excellence and Student Outcomes Framework (TEF) (Office for Students, 2018) is perhaps shaping the landscape more rapidly

through students seeking more industrial relevance from their studies. A cursory glance at the weekly academic vacancies suggests a post-TEF increase in the number teaching fellow posts where applicants are invited from 'professional engineers with industrial design experience' who are 'required to develop and deliver industrially realistic curriculum material' (University of Nottingham, 2018).

Whilst both initiatives have received plaudits from validation panels (University Quinqennial Review and Joint Board of Moderators course accreditation, 2015) and regularly feature in the free-text comments from students completing the National Student Survey (NSS), evidence of legacy building from these initiatives can be considered inconclusive. Despite the longevity of both initiatives and the overall positive nature of the evidence presented in this paper, there is a need to consider how both initiatives can make a strategic impact on the curriculum. This could be achieved through the lens of action research (Arnold and Norton, 2018) where each initiative is evaluated more rigorously to ensure that they provide lessons for benchmarking by the wider higher education community.

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