Murray, M., Hendry, G. and McQuade, R. (2020) Civil engineering 4 real (CE4R): co-curricular learning for undergraduates. *European Journal of Engineering Education*, 45(1), pp. 128-150. (doi: 10.1080/03043797.2019.1585762)

Civil Engineering *4* Real (CE*4*R): Co-curricular Learning for Undergraduates

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Key words: engineering education; problem-based learning; student learning; qualitative analysis; group interaction

Abstract

Vocational disciplines such as engineering provide an ideal opportunity for contextualising the curriculum. The provision of co-curricular activities can stimulate students to assimilate their prior knowledge and skills whilst enhancing employability attributes. Team-based co-curricular activities linked to problem-based learning (PBL) can offer students a quasi-authentic experience of engineering practice. In this paper, we provide a case study of a successful co-curricular initiative supported by local civil engineering employers. Civil Engineering *4* Real (CE*4*R) are evening workshops facilitated by practicing engineers, where student attendance is voluntary. Students use authentic documentation and collaborate in peer learning to solve industrial problems. CE*4*R has assisted student's anticipatory socialisation into their disciplinary profession. However, further research is required to establish the cognitive legacy that students gain from attending CE*4*R. There is also a need to explore the

synergy that could be prompted through understanding the boundaries between CE*4*R and the programme curriculum.

Introduction

The Dearing (1997) report could be considered a catalyst for a growth in the adoption of constructivist pedagogy in higher education (HE) given its promotion of active learning and practical experiences linking theory to professional practice. Subsequent reports (e.g. Watts, 2006; Lowden, Hall, Elliot & Lewin, 2011; Pegg, Waldock, Hendy-Isaac & Lawton, 2012) called for an authentic curriculum in HE that would contextualise learning and assist students to develop a professional identity. Within the engineering sector, a number of commentators have argued that these professional skills are best nurtured through closer industry-academia collaboration (Broadbent & McCann, 2016; Edward & Middleton, 2001; Royal Academy of Engineering, 2007):

> "It is vital to work with industry to frame the skills graduates need and highlight to students their relevance and importance. This is particularly important to encourage students to enhance their transferable and employability skills".
> (Engineering Professors Council, 2018)

Indeed, 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: 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). This remains important today, given that some students have been known to misconceive a professional engineer's day-to-day dealings (Hargreaves & Liston, 1996; Holmegaard, Møller Madsen & Ulriksen, 2016), and so, such a provision of talks allows for the opportunity to converse with experienced others (Inglis, 1941). Furthermore, students would like academics to use real-world examples in their pedagogy (Bather, 2011; Collins & Davies, 2009; Frymier & Shulman, 1995) and for academics to have had relevant industrial exposure (Neves & Hillman, 2016): something which is now more prominent in some job descriptors for academic posts, whereby applications are invited from professional engineers with industrial design experience who are "required to develop and deliver industrially realistic curriculum material" (University of Nottingham, 2018). Nonetheless, there is a paucity of engineering academics with relevant industrial experience within the UK higher education landscape (Tennant et al, 2015; Foster et al, 2017; Pilcher et al, 2017) and anecdotal evidence suggests that this can compromise the authenticity of the learning and assessment regime within an engineering curriculum. Academic role models tend to display research identities rather than the industrial disciplinary identities that would assist students to learn through mirroring "real-life situations and require the practising of the ways of thinking and problem solving employed by actual experts in relevant fields" (Kreber, 2013, p.19).

In light of these issues, the current paper is organised as follows. In the next section, we examine the call for HE to recognise the value of co-curricular/extra-curricular learning and the concept of hybrid problem-based learning (PBL). This is followed by an introduction to the Civil Engineering *4* Real (CE*4*R) initiative; a co-curricular series of evening workshops designed to combine prior curricular knowledge with real-life engineering problems and scenarios. The next section provides a justification for our research methodology whereupon we draw insights from selected student feedback. The following section provides a discussion of four key findings from our analysis (relevant learning; links (and gaps) identified between CE*4*R sessions and curriculum; importance/appreciation of problems being 'real'; value of team work) before we offer our overall conclusions to the research.

Co-curricular learning: a hybrid problem/project-based approach

There has been a growth in the number of references made to what students do outside the formal curriculum. Whilst some researchers (Wankel & Wankel, 2016) view co-curricular and extra-curricular as having interchangeable meaning, when we refer to 'co-curricular' we mean extensions of the disciplinary learning experience whereby students are able to assimilate knowledge and skills related to their professional practice within an academic programme. 'Extra-curricular' refers to activities that may be coordinated by an education establishment (sports clubs) or not (non-disciplinary employment), but may not be explicitly connected to academic learning. Kettle (2013) argues that participation in co-curricular and extra-curricular activities help to encourage students to become confident individuals, whilst Stefani (2017) suggests that co-curricular learning experiences are required to allow development of graduates over and above their chosen discipline-specific knowledge. The Chief Executive of the Engineering Professors' Council has recommended that university engineering departments "should create co-curricular opportunities to develop transferable skills and character alongside a demanding programme of studies" Rich (2018, p.226); of course, these proposals come a decade after the Burgess (2007) Report called for UK universities to adopt Higher Education Achievement Reports (HEAR). HEAR provides a means for students to document a comprehensive record of their achievements in HE, including evidence of eligible co-curricular activities and achievements (Higher Education Academy, 2015a); something which can prove to be extremely valuable, which will be evidenced in this paper shortly.

The Higher Education Academy (2018) provide a definition of (PBL) as "a style of active learning, PBL refers to learning opportunities that use real-world issues or problems to increase knowledge and understanding". The seminal introduction of PBL in the medical school at McMaster University – by neurologist Howard Barrows in 1969 – spawned its use across higher education worldwide (Barrows & Tamblyn, 1980). In the UK, the Royal Academy of Engineering have recommended that engineering courses should adopt more experiential learning techniques including team-based problem-solving activities so that students balance engineering solutions with societal, economic and environmental constraints (Royal Academy of Engineering, 2012). Given that the signature pedagogy in engineering education has been to apply deductive reasoning, PBL may introduce epistemological and ontological dilemmas for some academics and students. Nonetheless, there appears to be recognition amongst engineering scholars that educational theories such as social constructivism can be employed to soften a dominant technocratic curriculum. This is essential if we are to convince prospective students that the engineering discipline demands more than equation solving; that it requires creativity, continual social interactions, and team problem solving, too (Vesikivi, Lakkala, Holvikivi & Muukkonen, 2018).

Prince and Felder's (2006) evaluation of inductive learning in engineering education included problem-based learning and project-based learning, with the former tending to be more single-subject and structured, and the latter being more inter-disciplinary and realistic of industry expectancies (Larmer, 2014). They argue that the inductive approach tends to be favoured over traditional deductive pedagogy, referring to the similarities between 'problem' and 'project' based learning, and the effectiveness of hybrid approaches, denoted by the PBL acronym (Prince & Felder, 2006). Such hybrid models of PBL have some heritage in civil engineering education; for instance, Gavin (2011) found that students exposed to this form of learning considered their team working, design and communication skills to have been improved.

Moreover, participation in a PBL process also improved their learning during traditional lectures.

The emphasis that PBL places on team-based learning is aligned with the tenets of social constructivism, in that learners work collaboratively. Ashwin and McVitty (2015) have emphasised the importance of learning with others, and the necessity of doing so within higher education. Keenan (2014) suggests that peer-led learning sessions help students to acquire personal and professional skills with an enhanced sense of belonging, and that this agency can improve students' academic performance. Similarly, Mackh (2018, p.31) suggests that PBL "presents natural opportunities to form partnerships with local organizations, allowing students to gain first-hand experience in the world outside the classroom as they attempt to address genuine problems". Furthermore, Christiansen and Rump (2007, p.478) argued that "if engineering programmes should prepare students better for professional practice, they need to present students with authentic problems with complex problem-solving contexts". It would appear, then, that there is value in offering students the chance to work with their peers on real-world engineering problems, which is the backbone of the CE*4*R programme.

The Civil Engineering 4 Real (CE4R) programme

CE*4*R is a co-curricular (evening) initiative that encourages students to utilise prior knowledge from university studies and continual professional development (CPD) by applying them to real-life engineering problem scenarios. Open to all civil engineering students across the undergraduate programme, guest speakers proffer a real-life engineering problem to student groups of mixed ability and experience, who have circa two hours to work together and provide a solution(s). Broadbent and McCann (2016) recommend creating classroom values that resemble workplace values through experience-led learning. As such, the senior year students act as role models to fresher-type students (vertical integration) within inter-year teams, whilst industrial workshop presenters help to connect the world of learning with the world of work through presenting the students with a problem to solve. Through the provision of real engineering documentation, students are encouraged to integrate theory with context to experience – as far as possible – working as an engineer and developing an engineering identity. Research has stressed the importance of the inclusion of real-life engineers in such initiatives (e.g. Ring & O'Leary, 2010; Wankat & Oreovicz, 2015), and so, was pivotal for the authenticity of the workshops.

The lead author's motive and inspiration to label the workshop series as CE*4*R arose from a mix of latent contemplation (as a desire to expose students to industrial practice) and emergent thinking encapsulated through involuntary daydreaming and an early morning awakening from sleep (an "epiphany") in 2012. Thus, the CE*4*R 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). This recollected image is analogous to the epistemological tensions within the engineering education regarding the importance accorded to a continuum of deductive-inductive pedagogy. Other experienced scholars have reported similar episodes – Tosey (2006, p.30) referred to his own "3 a.m. [awakening] to find the metaphor of change as drama in my awareness". Critics might argue that the scientification of the engineering curriculum has made learning "too theoretical" whilst others would berate a return to "rule of thumb". To "be real" in the academy, to oneself, peers and to students is a nuanced journey for all academics. Traversing the landscape requires faculty to mediate between rational and emotional states, informed by institutional, faculty and departmental cultures that will influence what is considered to be authentic pedagogy. Whilst this explanation may appear convoluted, it resonates with a virtuous and moral practice of professionalism (Fitzmuarice, 2008) and a desire to advocate authentic personal reflection through praxis (Gibbs, Angelides & Michaelides, 2004). As such, the conception of CE*4*R as both brand and logo are the result of an intertwining of an academic (in both an ontological and epistemological sense) and personal life – a counter culture pedagogy (Parkinson, 2017).

Since beginning in the 2012-2013 academic year, sixty-seven two-hour workshops have been held on Monday evenings (5-7pm), and at the time of writing, the programme is about to begin its seventh year of development. Table 1 shows a list of the workshop titles broken down into generic sub-disciplines of civil engineering practice. The workshop title and/or the perceived prestige of the company delivering a workshop has played a significant part in attracting students to register for particular workshops. The title and content of each workshop is decided by the guest engineers (albeit some consultation is often required with the lead author to fine tune the problem(s) to be presented on the night). Securing industry cooperation to deliver CE*4*R has not been problematic and a 'snowball' sampling type procedure, using previous and existing industrial contacts from another initiative (industrial mentoring of 3rd year students) has ensured a willing supply of practising engineers who wish to participate. CE*4*R is also broadcast through the local community of employers through graduates taking their CE*4*R CPD certificates along to job interviews, and this has resulted in companies offering their engineers (including Alumni) as workshop presenters. This has an added win-win benefit for younger graduates as their participation in a workshop contributes evidence to their own initial professional development (IPD).

These workshops are optional and open to all undergraduates (circa *n=390* per annual academic session) including visiting European ERASMUS and international students who are enrolled on one of the department's two programmes (BEng (Hons)/MEng Civil Engineering & BEng (Hons)/MEng Civil & Environmental Engineering). In Scotland, the MEng course has a duration of five years. Whilst the undergraduate course curriculum provides students with number of authentic group work design challenges, CE4R offered further opportunities for real-world problem solving and offered an added advantage of vertically integrating students into groups with peers from all five years of the two programmes. As of May 2018, 357 students (86 female/271 male) attended one or more workshops over the six academic sessions resulting in 1571 student attendances (455 females/1116 males). Several students were stalwart supporters of the initiative with the top eight female attenders accumulating 181 attendances (12% of total attendances) and the top eleven male attenders accumulating 215 (14% of total attendances). In total, this created 3142 hours of student CPD whilst studying at university. Industry assistance is pivotal to CE*4*R and forty-five national/international civil engineering employers (21 consultants/19 contractors/5 clients) provided 132 workshop presenters to assist the students. Each workshop is based on a maximum of 35 students attending. The group composition (seven groups of five students) is arranged by the lead author prior to each workshop. A pragmatic approach is adopted based on a personal knowledge of the students registered on each attendance list. The intention is to ensure each group has a least one student who is known (based on prior observations) to be capable of promoting and managing interpersonal communication between peers (Peters, 2018) and to have a varied mix of students to promote diversity (gender/culture/experience), with an optimal group mix of all five years and no solo female student in any group (Beddoes, Panther, Cutler, & Kappers, 2016). The advantage of the evening attendance (albeit anecdotal evidence suggests the 5-7pm window excludes some students with part-time work or caring commitments) is that it requires a self-motive on the part of student to register, attend, and be an active participant within a team of students tasked with solving a real engineering problem. Whilst this idea may not be new – and it continues today whereby some students will attend professional engineering institution's evening lectures – CE*4*R is notably different through its active workshop format, which provides three kinds of educationally significant experiences as discussed Case (2008):

(i) students were exposed to a quasi-version of an engineering community of practice through their exposure to an authentic learning experience delivered by practicing engineers;
(ii) whilst the location of the workshops in the university prevented wider exposure to this community, the students were able to develop a professional rather than academic identity as 'engineers in training'; and
(iii) exposure to an engineering discourse (language, mathematical formula, artefacts, non-verbal behaviour) through observing the practitioners and enacting their own discourse amongst peers during the workshop activities.

INSERT TABLE 1: CE*4*R Workshop Titles 2012-2018 (n=67)

Methodology

Although the project has obtained both qualitative and quantitative data from participants, the current paper focuses solely on the qualitative aspect, where free-text verbatim feedback was analysed using thematic analysis (see Braun and Clarke (2006) for further detail). This approach allowed exploration of the students' personal experience of taking part in the CE*4*R programme.

Data for the current paper comes from the first five academic years' (2012/13 – 2016/17) of student feedback pertaining to fifty-five CE*4*R workshops. At the end of each workshop, students were asked to complete a feedback form containing a number of Likert-scale questionnaire items (not examined in this paper) and a free-text question: "please write a few lines about your experience participating in the workshop". Free-text responses can be susceptible to being completed quickly with a limited number of words, often lacking sentence structure (Rich, Chojenta & Loxton, 2013), and there is a paucity of guidance on why and how free-text responses are incorporated into a research questionnaire (Garcia, Evans & Reshaw,

2004) and whether they should be considered qualitative or quantitative data (O'Cathain & Thomas, 2004). However, Ellonen, Fagerlund and Poso (2016) highlight that free-text comments can provide insight not otherwise gleaned from research, and are used annually by the National Student Survey (NSS, 2018), so in the current study, we believe that the free-text responses from students are sufficiently rich in detail and worthy of evaluation and exposure.

There were 1302 student attendances across the five years, though these are not necessarily different students, as students could come to any session they liked over the course of their degree. 777 comments were received from 1183 returned questionnaires, and data has been kept on secure, password-protected devices that only the research team could access. Due to the longitudinal nature of the data – in that it has been collected over five years – it is not possible to compare data across year groups given that the same student may have attended workshops from their first through to their fifth year.

Data analysis

The 777 comments received in answer to the survey question ("please write a few lines about your experience participating in the workshop") were thematically analysed using Braun and Clarke's (2006) six-stage approach; a method for "identifying, analysing and reporting patterns within data" (p.6). Themes have been defined as descriptions of a phenomenon that are important to the speaker (e.g. Daly, Kellehear & Gliksman, 1997) and are identified across the data set following a process of (1) becoming familiar with the data, (2) coding, (3) searching for, (4) reviewing, (5) defining and (6) naming. Such a process is iterative, and in the current paper, followed the inductive approach of Boyatzis (1998). The application of thematic analysis to such free-text questionnaires has been explored previously (e.g. Garcia et al., 2004; Hilgart, Phelps, Bennett, Hood, Brain & Murray, 2010; Phelps, Wood, Bennett, Brain & Gray, 2007).

This process was undertaken individually by all three authors, who then combined the most salient results to produce the following end themes:

- General positivity
- Inspiration

- **Learning experiences**
- **Relationship with curriculum**
- **The real world**
- **Value of peer learning**

The first two themes listed above – general positivity and inspiration – pertained to students' inclinations towards the workshops, detailing enjoyment as a result of the stimulating and supportive work environment, in addition to inspiring their passions for working within the engineering industry in future. Whilst these issues are of large interest to the authors, for the sake of brevity and to allow sufficient elaboration of the remaining four themes (which required considerably more 'unpacking'), they are not examined directly within the current analyses. However, they quite clearly underpin the upcoming analytical discussions, and thus, remain prominent issues nonetheless.

Analysis

The paper will now detail the themes of (1) learning experiences, (2) relationship with curriculum, (3) the real world, and (4) value of peer learning.

Theme 1: Learning experiences

Research has shown that PBL can facilitate a greater understanding around a subject in comparison to more traditional methods of learning (e.g. Distlehorst, Dawson, Robbs & Barrows, 2005; Dochy, Segers, Van den Bossche & Gijbels, 2003; Mergendoller, Maxwell & Bellissimo, 2006; Roche, Adiga & Nayak, 2016). One of the aims of the CE*4*R programme is to deliver an authentic learning experience, and whilst there were numerous responses in the data corpus pertaining to learning occurring (e.g. "*I feel that I have come away with more knowledge*"), more insightful student answers detailed exactly *what* was learned. The analysis begins, therefore, with a focus on responses that clearly identified the learning experiences that had taken place through participating in the CE*4*R programme:

> *"it provided new information on steel structures"*
> *"Expanded my civil engineering vocabulary"*

"I picked up some new knowledge on geotechnical engineering"

Williams (2005) discusses authentic learning in terms of students taking responsibility for their own learning and applying knowledge to practical problems. In the above quotes, we can see that students have identified specific knowledge they have gained from participating in the workshops and applied it to certain aspects of their degree course. Responses also pointed to more generic transferable skills that were obtained in the workshops, such as thinking skills (*"thinking through the problem improved my engineering skills"*; *"helped me understand the design process better"*) and team work skills (*"I felt like I gained understanding by being involved"*), though it is noted that these in isolation do not constitute learning (Dearing, 1997).

Demonstrating that learning has occurred is notoriously difficult; students can say that they have learned, but it can be difficult to demonstrate such knowledge and understanding. Scott and Yates (2002) detail a series of studies in Australia that point to students perceiving universities to be of higher quality when they provide learning content and experiences that are demonstrably relevant to subsequent professional practice, and indeed, data from the current corpus points at this too:

"It was great to learn from professionals in the field about design and construction costs"
"It gave a great insight to what goes into being a structural engineer in a design office"
"It has given me a better idea of how civil engineering problems are addressed by industry professionals"

This application of theory (university, current curriculum) to practice (industry, future careers) will be further discussed in the following themes, but it is encouraging that students appear to be making this link as, as reported by Dearing (1997), there is a consensus among educators that depth of understanding is encouraged through promotion of the links between theoretical and practical aspects of a subject, and by taking an active approach to learning. For instance, one student's reflection that the workshops provided *"a very good insight into how engineering principles are undertaken in practice"* suggests that they could see how class content (i.e. engineering principles) can be applied in industry.

In addition, students also commented on the relevance and value of what they were learning more generally:

> *"the problems were complex and very relevant to the workplace"*
> *"Really interesting and relevant… applicable learning"*
> *"applicable and relevant to actual work"*

Noting such "relevance" of topics again suggests that students are making connections (anticipatory socialisation) between the academic content of their university curriculum, and the real-world industry that they will be entering upon completion of their degree. For students without prior industrial experience, this may be their first experience of an 'identity transition' to that of 'engineer in training'. CE*4*R could be considered to provide the attendees with a moderate form of legitimate peripheral participation (Lave and Wenger, 1991) through providing temporary access to the practising engineer's community of practice (Wenger, 1998). The utility of their theoretical knowledge being a symbolic artefact of the socialisation and identify transformation. This is particularly important, given that research has identified that the content of some higher education engineering programmes is not relevant, leading to students' expectations being poorly met by their study programmes, and resulting on students, on arriving in higher education, finding it hard to recognise the engineering they applied for (Holmegaard, Madsen & Ulriksen, 2016). This relationship between curriculum content and industry practice is the focus of the next theme.

Theme 2: Relationship with curriculum

The provision of an authentic curriculum that contextualises learning and develops the generic skills and competences required by employers is seen as essential (Lowden et al., 2011; Pegg et al., 2012). It is encouraging, therefore, to see that students recognise the application of the CE*4*R workshops to their curriculum:

> *"it helped to relate the coursework to an industry problem"*
> *"involved quite a bit about what I'm doing… in class"*
> *"it has enhanced my learning from class"*

Students also established explicit boundaries between their university experiences and the professional engineering world, orienting to the applicability of learned content *("good to see where knowledge from the course can be applied"*; *"well detailed problems and relatable to class"*), and highlighting the uniqueness of the workshops, in that they enabled their creativity (*"I enjoyed using knowledge gained from my course in a more creative way")* and opened them to the practicalities of industry-based engineering (*"informative and interesting due to the fact that it's different to normal examined curriculum"*). They also identified learning opportunities from CE*4*R that they had not experienced yet in class though suggested they would like to:

> *"although I have yet to learn about piling and groundwork I found it interesting"*
> *"the topic has not yet been taught at university even though it is very important"*
> *"it would be nice to have something like this introduced into lectures"*

Such recognition of learning gaps maps entirely onto the ethos of PBL which encourages intrinsic motivation and independent learning (Dolmans & Schmidt, 2006), with such autonomous learning being deemed as a "vital requisite" to be able to function effectively in modern society (Boud, 1988; p.8). This highlights the realistic value of the workshops in that they are encouraging students to be actively involved in their learning which is another aim of PBL (Yew & Schmidt, 2009).

Despite this, responses also identified disparities between the workshops and the university curriculum; highlighting aspects that are missing from the latter:

> *"Very informative and insightful using a topic otherwise largely ignored whilst learning about civil engineering"*
> *"Great insight into industry problems; an insight that is missing from university classes"*

Whilst it is encouraging to see further evidence of students' engagement with their studies – in that they can clearly elucidate what they are being taught – such comments highlight a need for perhaps more applied education in the classroom. Acknowledging that certain topics are "ignored" or "missing" suggests that these students are gaining something from the CE*4*R workshops that contribute to their education over and above their degree programme. Whilst this is encouraging for CE*4*R, it too highlights that the Engineering curriculum at hand – although renowned for its degree programme – still has improvements to be made to ensure they are delivering the best possible education to students, to make them employable upon leaving university (Markes, 2006). An abundance of research (e.g. Andrews & Higson, 2008; Helyer & Lee, 2014; Martin, West & Bill, 2008; Mills & Treagust, 2003; Stein, 2004) suggests that one way to enhance such employability is to ensure that students are receiving teaching and learning experiences that are as akin to real life as possible, as discussed in the next theme.

Theme 3: The real world

The third identified theme – and the one which was most commonly found in analysis of the data corpus – related to the authenticity of the workshops. Students viewed these workshops as being reflective of what an engineering job *actually* entails; something which may suggest exposure to predominantly traditionalist teaching methods in their degree studies (Johnson & Ulseth, 2014). PBL research has often highlighted the importance – the criticalness – of the design of the 'problem' (see Hung [2016] for a discussion), and student feedback certainly valued the fact that CE*4*R workshops were based upon real industry scenarios:

> *"this helped me get a look into real problems the industry face"*
> *"interesting to use real life examples: it made it more exciting"*
> *"it was good to see real engineers and hear what kind of problems they deal with"*
> *"chance to be taught by a practicing engineer gives a real edge to the situation"*

Such findings are perhaps not unexpected. Bather (2011, p.212) reports that the civil engineering students show "a strong preference for their learning to be directly related to the real world of civil engineering work". This concept of learning being put into context with real world scenarios can be traced as far back to the works of Dewey (1929) and the onus on learning in response to, and interaction with, real-life events. Taking note of such comments – and the fact that students, rightly or wrongly, appear to consider their degree programme as not 'real' engineering – suggests that the university curriculum may be able to do more to merge the barrier between theory and practice. Points like, *"it was a good way to understand real-life geotechnical problems"* and *"I learned a lot about real engineering"* suggests that the curriculum-taught approach to the topic is perhaps not as realistic as it could be.

In addition to emphasising the value of engaging with real-life problems in the workshops, students also made reference to post-university life, drawing upon the key role that the workshops play in preparing them for future career ambitions:

> *"good to find out more information about what we can do in our future careers"*
> *"it helps to get a feel for what you are working towards in your degree"*
> *"good to have an overview of… civil engineering, particularly during my fifth year when I need to consider a career"*

Almost forty years ago, Brillhart and Debs (1980) observed that students who enrolled on a course of study towards a career in engineering tended to have very little knowledge of the various roles and responsibilities undertaken by engineers. Although more recent research is attempting to address such issues (e.g. Itani & Srour, 2016), such comments suggest that students are still not fully aware of what a career in the field will entail. Indeed, Hargreaves and Liston (1996) highlighted that the necessity for engineering students to possess strong abilities in mathematics and physics can lead to a "misconception of what a professional engineer deals with in a day-to day life" (p.169), so it is perhaps a little concerning that some students appear to be unsure as to what their career paths may be, as evidenced by one student: *"it did not help confirm that I wish to become a civil engineer"*.

However, other responses recognised the challenges of industry, suggesting that they are prepared for the world of work upon completion of their degree:

> *"this helped me give a view on how the industry works and seeing problems that I am likely to face after university"*
> *"a good view into industry and the problems we will all face"*
> *"I will definitely take this learning into the industry with me"*
> *"this was a real-life problem that I could encounter when I graduate"*

Research has highlighted the need to convince prospective engineering students that engineering involves problem solving (Mitchell, 2015; cited in Shaw, 2015), so it is encouraging to see that students are already applying the knowledge they are gaining whilst still at university to their prospective careers; focusing specifically on their problem-solving abilities. Again, this links closely with one of the fundamental principles of PBL; that problems should be as realistic as possible (Abrandt Dahlgren & Dahlgren, 2002; Wiggins & Burns, 2009).

Theme 4: Value of peer learning

The final theme focuses on students' perceptions of working together in small groups in the workshops. After registering to attend CE*4*R, they are arranged in groups set by the CE*4*R programme leader (lead author on this paper) to ensure that each group comprises a mixture of students (with different levels of knowledge and experience; from first year to fifth-year MEng, where possible. The gender composition of each group is intended to ensure that there are no solo female students. Where senior female students are known to have undertaken several summer industrial placements, the intention has been for them to be paired with junior female students as role models. However, on occasion, a sole female student who is known to have secured significant industrial placement experience, is designated (by intent, rather than formal request) a quasi-leadership role within a group of males who have none/limited previous industrial experience. Anecdotal observations of group interactions during the workshops suggest that these solo female students have sufficient self-confidence to take on an emergent leadership role. The industrial experience appears to provide these students with 'expert power' (French & Raven, 1959) enacted through the deployment of explicit and tacit knowledge as an aid to promoting effective discussion during the problem-solving activities. This is at odds with research (Dasgupta, McManus-Scircle & Hunsinger, 2015, p.4992) that found that "women were more likely to speak up in group problem-solving if assigned to female-majority groups compared with female-minority groups".

Several students noted their initial apprehensions of peer learning, in that were expected to work with colleagues they had – potentially – never interacted with before. Furthermore, some students were anxious about working within different year groups, as they anticipated incompatibilities between their prior knowledge and senior year peers (e.g. year one as being 'inferior': "*I don't understand the technical words"; "I could not make much of an input due to lack of knowledge as a first-year student*") and those in the latter phases of their degree (e.g. year five being 'too advanced'):

"I was apprehensive about working with peers in a group"
"Was very difficult with being from first year"
"I felt as a first year taking part in this workshop that naturally my knowledge was not as strong as the others"

These criticisms relating to group formation align with previous findings in engineering research (Pinho-Lopes & Macedo, 2016), in that facilitators opt for heterogeneous groups as means of diversifying the group dynamics. Furthermore, they lend some credence to Kirschner, Sweller & Clark's (2006) criticism of constructivist pedagogy. By constructing groups of various skillsets and degree levels, a realistic insight into the expectations of real-life, professional engineering is made possible, but in doing so, these manipulations also come with some level of resistance from students at first. However, upon attendance at the workshops and being immersed in the problem cases, mixed year groups were eventually viewed as a highly positive dimension of their teamwork experiences. Students discussed the benefits of mixed year groups as enabling rich knowledge stances, encouraging meaningful learning, and as creating an interactive culture of peer-support:

"Great to work… with students from different years to combine difference ideas and experience levels"
"good to work with other students to give different viewpoints"
"The older students were really good at explaining things to first year level"

Many students also saw the workshops as a unique opportunity to engage with their peers; regardless of academic level. They drew upon the shared goal of advancing their grounding in civil engineering as a means through which they could work collectively. In this way, the initial concerns regarding academic seniority/power struggles were overridden (Warnock & Mohammadi-Aragh, 2016):

"A good opportunity to meet other students from different years"
"…first years and fifth years can think on the same wavelength, showing how we are all developing our civil engineering way of thinking"

Finally, students too identified the personal benefits they had obtained from working in groups; developing attributes that they could transfer to other areas:

> *"Highly complicated for a first-year student but in the end I understood due to my team mates"*
> *"I started thinking outside the box due to the combined thinking by the group"*
> *(Working with others) "Helps gain confidence in group tasks"*

This evidence of transferable skills (team work, developed thinking, confidence building) is encouraging, as a number of research outputs have argued that such skills are best nurtured through closer industry-academia collaboration to ensure that students are exposed to real-industry practice and graduate thinking like professionals (Alpay, Ahearn, Graham & Bull, 2008; Artess, Hooley & Mellors-Bourne, 2017; Confederation of British Industry, 2009; Dunsmore, Turns & Yellin, 2011; the Royal Academy of Engineering, 2007; Spinks, Silburn & Birchall, 2006). In addition, it has been noted that group collaboration/team work is a key factor is student learning and motivation (Hmelo-Silver, 2004) and so, again, it is reassuring to see that the group work aspect of the workshops is – on the whole – favoured by the students.

In summary of this analysis, then, we have highlighted four key findings that will be discussed in the final section of the paper:

(i) Specific/ relevant learning has taken place
(ii) Links (and gaps) have been identified between CE*4*R workshops and the curriculum
(iii) Importance/ appreciation of problems being 'real'
(iv) Great value is placed on the team work element

Before this, however, there will be a brief overview of feedback responses from CE*4*R industry collaborators.

CE*4*R industry collaborators

Feedback from the industry speakers corroborated the positive student perceptions of CE*4*R and provided insightful comments regarding its future. More detailed analyses of this industry feedback will be conducted in future publications, but it is important to shed light on the responses of the involved partners pertaining to their perceptions of the CE*4*R workshops, albeit briefly:

CE*4*R predominantly involves university alumni as workshop facilitators, and not only did this provide a source of inspiration for the students, analyses of the industry feedback illuminated the sense of community (*"nice to be back in my old stomping ground"*) and the fulfilment (*"rewarding experience…to be involved in"*) attained by returning graduates in supporting new generations of future engineers. These industry collaborators commended the structure of the PBL groups (*"great idea to integrate the different year groups…to problem solve a real project"*) as well as the adaptability of the students (*"impressive to see how some of them quickly picked up on things"*), given the unfamiliarity of the workshop's social dynamics (*"considering it's a mix of all years, it is unlikely that they will have spoken much before"*; *"to see some of the tables really quickly behave as teams is a testament to the CE4R programme"*). Additionally, the industry collaborators noted that CE*4*R was a *"learning experience"* from their perspective also, and one speaker pointed to potential tweaks in the course as means of enhancing the student experience (*"it would be benefitted from perhaps a little more direction before they split into groups, as all the teams were a bit stuck as to where to start"*).

Discussion

Relevant Learning

Students engage and are enthused by authentic and relevant engineering experiences (Engineering Professors Council, 2018). The topics covered in the workshops provided the students with a wide range of sub-disciplinary knowledge and exposed them to the professional identities associated with the civil engineering discipline (Mills, 2011). However, CE*4*R is not focussed on the transmission of explicit knowledge per se; the real learning gain is achieved through how students deploy and share their own prior learning and tacit knowledge during the problem-solving activity. As Kamp (2014, p.15) has argued, "the *how* we teach will become equally or more important than what and how much we teach". For students without previous industrial experience, the project documentation was mostly novel and sometimes confusing. Thus, it could be argued that these students were in a state of liminality and that the mechanics and customs of the engineering problem solving process is akin to what Meyer and Land (2005) refer to as a 'threshold concept'. The students apply their own cognitive abilities and are assisted by their peers – and the guest engineers – to make sense of this ‘problematic’ knowledge. In doing so, they take on a new engineering identity through appreciating how different real industry problems are in comparison to the overtly theoretical constructs found within summative examination papers. Mackh (2018, p.238) contrasts this behaviourist approach to learning with a constructivist approach such as CE*4*R:

“When we link knowledge, information, and theory to practical examples and application, our students simply learn more effectively. And when these connections directly support our students’ career preparations, the results are even more powerful”.

The power noted by Mackh (2018) is played out in the way that CE*4*R has positively influenced the students’ self-confidence and determination to succeed at university. Student responses suggest that the use of authentic documentation, combined with real engineering problems, delivered by practicing engineers, provided the students with the ‘heart and soul’ of the discipline. This has reputational prestige capital given that students are known to perceive value gain from universities that provide learning content and experiences that are demonstrably relevant to subsequent professional practice (Scott & Yates, 2002). Similar to the present analytical findings, Kirn and Benson (2018) also found that engineering students were most engaged in their learning when the content was perceived to be explicitly relevant to their future career; regardless of task complexity. Where the learning was deemed to be irrelevant to what they envisaged as beneficial to future career roles, they were considerably less motivated, and significantly more likely to withdraw from the problem tasks at hand.

Links (and gaps) identified between CE4R sessions and curriculum

It is evident that formalising the student CE*4*R experience could be achieved through encouraging students to leverage the learning gain from their attendance and to link all of their curricular, co-curricular and extra-curricular learning through reflective practice. Indeed, one student who was a regular attender displayed his own agency through a series of blogs about his participation in the workshops; whilst the narrative is mostly descriptive, there are exerts that very clearly display metacognition (see McGarvie, 2018). Indeed, a study of engineering students (Kilgore, Sattler & Turns, 2013) has demonstrated the usefulness of employing reflective portfolios to enable students to capture the learning from extra-curricular activities, and to enable them to construct their own engineering identities.

Clegg and Bradley (2006) have suggested that personal development planning (PDP) is easier to introduce into courses where the curricula are subject to external influence linked to the professions. Currently, the department does not provide students attending CE*4*R with a formal (credit bearing) opportunity to document and link such PDP to their upcoming graduate initial professional development (IPD) through this and other examples of continuing professional development (CPD) whilst studying at university (see for example Houghton and Maddocks, 2005). Whilst this is regrettable, it reflects a tension between the time available for assessing the disciplinary knowledge within the formal curriculum, and the competing values that different academics (and indeed course validation committees) place on the assessment and/or evaluation of experiential learning undertaken by the students. Moreover, the university – like others in the UK – has not adopted the recommendation made by Burgess (2007) for a HEAR that would require students to adopt a PDP mind-set to disclose to employers the richness of their experiences and achievements during their university studies.

Importance/appreciation of problems being 'real'

The problem(s) presented to the students were as authentic as possible, where they incorporated real documentation (i.e. drawings, specifications, photographs, reports) from current or historic projects. The verbatim presented previously demonstrates that this authenticity has enhanced the students' anticipatory professional socialisation (Edward & Middleton, 2001; Garavan & Murphy, 2001; Keltikangas & Martinsuo, 2009) about their future career. Additional feedback indicates further evidence of legacy regarding employability capital:

> *The CE4R workshops were invaluable at my assessment centre yesterday with WSP, as the group exercise was very similar to how I solve problems during CE4R. I received a phone call this afternoon saying that they wanted to hire me and they particularly liked how I worked within the group to solve the exercise. They positively praised how I presented knowledge to other potential candidates during the task without forcing ideas upon everyone and how I tried to get the whole group involved. Without CE4R workshops I feel I would have struggled with the group exercise".* (Unsolicited email from MEng graduating student, 2015).

The students self-reporting of their own and group problem solving behaviour during the workshops suggested that they had undertaken elements of analysis and synthesis, and that they had engaged in creative thinking. Although our analytical approach did not capture/measure the dynamics of the communication and cognition within the CE*4*R groups, the lead author's role in facilitating the workshops (as a participant observer) provides anecdotal evidence that the outcomes of the problem-solving process were sometimes novel, innovative and indeed useful guidance for the industrialists. That the students were developing 'real habits of mind' and 'real ways of thinking' like an engineer appeared to be evident, which align with a growing body of knowledge in this area (Atman, Adams, Cardella, Turns, Mosborg & Saleem, 2007; Yildirim, Shuman & Besterfield-Sacre, 2010).

Value of team work

The CE*4*R workshops provided students with a surrogate version (role play) of an engineering workplace, requiring them to cooperate as a cohesive team engaged in a time-bound problem-solving activity. This appeared to engender a feeling amongst the students that they were collaborating as "student engineers, rather than [as] engineering students" (Lindsay, 2008, p.35), aligning with related research where engineering students noted their appreciation of the realism offered by enhanced team spaces within the campus (Grulke, Beert & Lane, 2001). In contrast to these findings, Koro-Ljungberg, Douglas, McNeill, Therriault, Lee, and Malcolm (2017) found that – despite the authenticity of the problem-solving tasks – within the university environment, students tended to maintain their *student* identity, rather than transitioning towards that of the 'emerging engineer'. However, previous research has shed light on the intricacies of student identity management, whereby students negotiated displays of power (e.g. professional identities/terminology) in subtle – and often conflicting – ways as means of encouraging equal group status, and thus, team harmony (see Benwell and Stokoe, 2002); a possible explanation for the aforementioned findings.

It must also be noted that the nuanced organizational culture and social dynamics played out in professional engineer teams (i.e. issues relating to trust, commercial risk, legal contracts and conflict) are impossible to truly authenticate in student teams. However, CE*4*R promoted collaborative practice and collegiate behaviour within the student groups, albeit a sanitized version of a real interdisciplinary and interorganisational project engineering team environment. Nonetheless, given that CE*4*R takes place in the evening, and attendance is voluntary and non-credit bearing, it could be hypothesised that the informal climate prevalent during workshops helped to de-risk some of the traditional problems that are known to result in engineering student team projects becoming dysfunctional (Aman, Poole, Dunbar, Maijer, Hall, Taghipour, & Berube, 2007; Shen, Prior, White & Karamanoglu, 2007). Indeed, Hockings, Thomas, Ottaway and Jones' (2018) study of independent learning undertaken by students revealed that peer learning was highly effective for non-assessed work, and so suggest that it should be implemented into the student learning experience.

Conclusion

In addition to the highly encouraging student feedback examined in this paper, CE*4*R has received plaudits from course validation and accreditation panels, and has been specifically named and commended in the free-text comments section of the annual National Student Survey (NSS). Furthermore, we suggest that CE*4*R is aligned with some aspects of globally leading pedagogy in engineering education identified in a report commissioned by the Massachusetts Institute of Technology (MIT). CE*4*R has provided students with "a wide range of technology-based extra-curricular activities and experiences" based on "experiential learning" in association with "longstanding partnerships with industry that inform the engineering curriculum" (Graham, 2018, p.30), and as a result, the aim is now to expand the use of CE*4*R within daytime curriculum, albeit, in very limited manner compared to the successful cross-faculty Integrated Engineering Programme (Roach, Tilley & Mitchell, 2018) initiative at the University College London (UCL). Nonetheless, there does appear to be valid reasons for maintaining co-curricular studies given they can encourage student dispositions to stay and succeed at university. Research undertaken in the USA found that "participating in co-curricular activities that are major-specific may be linked to increased academic emotional engagement through pathways of self-efficacy" (Wilson, Jones, Kim, Allendoerfer, Bates, Crawford, Floyd-Smith, Plett & Veilleux, 2014, p.645). Moreover, through their exposure to a professional network of engineers, the students who attended CE*4*R were able to develop their career management competencies in relation to their intended occupation (Jackson and Wilton, 2017). After every workshop, each student is awarded a CPD certificate bearing the logo of the presenter's employer. Anecdotal evidence has revealed that some students are taking these to placement and graduate job interviews so as to provide evidence of their commitment to their learning and the profession. As such, the certificates are a symbolic representation of a bridge spanning between the novice student and professional engineering communities.

However, if we are to enhance future implementations of PBL in our civil engineering curriculum and co-curriculum, it is necessary to acknowledge the challenges experienced here by the student groups. For instance, some students raised the difficulty of the cases and documentation presented by the industry contributors as hindering their overall experience. It may well be the case that students require more support (scaffolding) in terms of understanding the content and real-life knowledge complexities of the workshops. The discomfort associated with the unfamiliarity of PBL is a common pedagogical issue (see Warnock & Mohammadi-Aragh, 2016). In regard to CE*4*R, this could be due to a divergence between the guest engineers' epistemic beliefs and those of students, given that their exposure to problem solving within a research-intensive university tends to be dominated by 'high summative assessment loads and examinations' (Tomas and Jessop, 2018, p.8) employing closed-ended problem solving.

Similarly, the novelty of PBL (i.e. the newfound learner autonomy it places upon its students) may raise some discomfort among novice PBL tutors (e.g. the fear that students will become distracted from their group work as a result of engaging in irrelevant or off-topic discussions during the PBL sessions) amongst academics who are more accustomed to didactic methods (Hendry, Wiggins & Anderson, 2016). This can lead to premature or overly direct interventions made by inexperienced PBL tutors, which can be highly detrimental to students' *own* collaborative efforts (Aarnio, Lindblom-Ylänne, Nieminen & Pyörälä, 2013). For example, if meaningful learning is to occur in PBL, students must experience some degree of cognitive conflict (i.e. the misalignment between what they already know, and the requirements of the problem to be solved) (De Grave, Boshuizen & Schmidt, 1996), and it is through their debates with one another that rich knowledge stances are acquired, and deeper learning occurs in arriving at successful solutions (Aarnio et al., 2013). Recent interactional research involving PBL in engineering has shown how students – even in the absence of the tutor – exhibit effective self-management strategies during knowledge disagreements (McQuade, Wiggins, Ventura-Medina & Anderson, 2018), which reaffirms the point that students must be given the educational freedom to negotiate these critical discussions themselves. Therefore, if the open-ended nature of PBL is to be sustained, new PBL tutors must be sufficiently supported in making the transition towards facilitator of student-centred learning (Azer, 2005).

Rehearsal for closed-ended problem solving exam questions typically fits with the "plug and chug; cram and flush" behaviour identified by Bella (2003, p.33). Students engage in rote learning and 'hedge their bets' based on revising past exam papers. Despite any potential gains of this instrumental behaviour, it leads to a distortion of how students conceptualise their own knowledge construction, and short-circuits the propensity for students to undertake metacognition. Thankfully, there has been a growing interested in how students (Fryne, Montford, Brown & Adesope, 2012; Faber & Benson, 2017) – supported by engineering faculty (Montford, Brown & Shinew, 2014) – establish and develop their personal epistemic assumptions, and in particular, how this influences the efficacy of open-ended problem-solving tasks undertaken by students (Douglas, Koro-Ljungberg, McNeill, Malcolm & Therriault, 2012; McNeil, Douglas, Koro-Ljungberg, Therriault & Krause, 2016).

Future research

Given the push towards collaborative learning in engineering (e.g. PBL), it is important to examine the social processes (i.e. what the students are actually 'doing' in their learning) involved in student group work (Imafuku & Bridges, 2016). For instance, self-reported data holds clear limitations in terms of bias; that is, students providing what they believe to be the correct answer, and thus, deflecting from their *actual* practices (Winne & Jamieson-Noel, 2002; Kirn & Benson, 2018). Instead, by focusing on naturalistic group interactions 'in action', capturing student communication and cognition during the CE*4*R problem solving process would be a valuable addition to this research (i.e. what arises from the PBL interactions themselves). Benchmarking previous studies employing theoretical constructs of group interaction behaviour (Firestien & McCowan, 1988; Cooke & Szumal, 1994) and "industrial and organizational psychology research" (Borrego, Karlin, McNair & Beddoes, 2013, p.497) would help inform our understanding of how the students perceived their 'teamness'. Furthermore, establishing how the students interacted their conceptual knowledge (knowing what) and procedural knowledge (knowing how) to resolve the problem(s), as an aid to develop their engineering skills (McCormick, 1997; Taraban, Definis, Brown, Anderson & Sharma, 2007; Leppävirta, Kettunen & Sihvola, 2011) would help to advance our pedagogy practice. However, it has been argued that 'theoretical knowledge does not in and by itself lead to improved authentic problem-solving skill' (Christiansen & Rump, 2007 p.478). Whatever the case, it is evident that for any of the proposals noted, the researcher(s) should be cognizant of the implications of gender composition in group work (Dasgupta McManus Scircle &

Hunsinger, 2015; Beddoes & Panther, 2018) and a need to promote inclusion and diversity within engineering education (Peters, 2018).

An alternative lens to view the problem-solving activity would be through social constructivism; in particular, situated learning, whereby the novice students engage in a light form of legitimate peripheral participation (Lave & Wenger, 1991) with peers and industrialists who have advanced experience and knowledge. This behaviour is also aligned to Vygotsky's (1978) zone of proximal development (ZPD) in that that students who have industrial experience (see Davies & Rutherford, 2012) and industrialists, provided scaffolding to support the less able learners (Harland, 2003). Furthermore, given that CE*4*R bridges the boundary between the communities of student engineers in training and practising engineers, there would appear to be worth in examining the workshops through a 'community of practice' lens (Wenger, 1998). Whilst the feedback from students does not explicitly mention a transition in their identities, it is clear that CE*4*R is contributory to the students 'becoming' more engineering like through a gradual indoctrination to engineering language, artefacts and ways of thinking and reflecting. Thus, CE*4*R supports Watts (2006, p.21) assertion that 'the need for realism in relation to the world of work provides a compelling rationale for the active involvement of practising engineers in the design and delivery of programmes'. These 'pracademics' (Pilcher, Forster, Tennant, Murray & Craig, 2017) are typically employed as teaching fellows and have become more ubiquitous within higher education in the UK following the introduction of a Teaching Excellence and Student Outcomes Framework (Office for Students, 2018).

Exposing the students to real engineering through mentoring by graduate engineers is one way to enhance the students' industrial experience (Murray, Ross, Blaney & Adamson, 2015). Industrial placements provide an optimum combination of education, training and experience (Engineering Professors Council, 2018). However, despite a call for the academy (Peters, 2018, p.42) to encourage and support all (and as a means to raise the number of "underrepresented students" securing placements) of our students to seek work experience, in the UK, there is evidence of an undersupply of disciplinary placements (Lamb et al, 2010; Perkins, 2013). Moreover, recent research (Tennant, Murray, Gilmour & Brown, 2018) found a significant gap between the demand and supply of disciplinary placements available to civil engineering students across four universities in Scotland.

In the UK, the recent introduction of degree apprenticeships ('graduate apprenticeships' in Scotland) combines situated learning and training with university study (Engineering Professors Council, 2017) and affords the student employee a high degree of agency through their participation in identifying and negotiating work-based learning and assessment tasks as part of their learning plan. For HE institutions, offering degree apprenticeships there is an opportunity to capitalise on the industrial problem-solving experiences (domain-specific procedural knowledge) of the apprentices to inspire, motivate and excite their peers enrolled on the traditional full-time course. This could take the form of mini-CE*4*R type workshops whereby the apprentice engineers become more akin to students as partners (Higher Education Academy, 2015b) in their own learning, their peers learning, and indeed, their tutors learning about Civil Engineering *4* Real.

Acknowledgement

The authors would like to express our sincere gratitude to the three referees for their suggestions on how to improve the scholarship in the paper.

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Substructure ,Tunnelling & Geotechnical

- *Foundation Arrangements over a Rail Tunnel in Glasgow*
- *Glasgow Concert Hall: Piling within a live retail environment*
- *High-Rise Urban Hotel Buildings: Design of Complex Foundations*
- *Tunnelling on the East End Regeneration Route.*
- *Technical Issues in the Glasgow Subway Refurbishment*
- *Design & Construction Challenges in Tunnelling*
- *Dumfries Learning Town North West Campus-Groundwork's Problems*
- *Greenock Health & Care Centre - Overcoming Contamination Challenges*
- *Ayr Academy 4G Sports pitch.*
- *Wind Turbine Construction in Difficult Ground Conditions*
- *City Centre working-geotechnical challenges*
- *Basements & Piling*

Infrastructure

- *Replacement of a Railway Bridge Superstructure*
- *Gleneagles Station Link Road: Route Options*
- *Edinburgh Water Strategy & Resilience*
- *M8 M73 M74 Motorway Improvements Project*
- *Haymarket Station Project, Edimburgh*
- *Trunk Road Route Assessment in Scotland*
- *Queen Street Station Redevelopment: Everything you wanted to Know but were Afraid to ask*
- *Edinburgh Glasgow Improvement Programme (EGIP) Advance Works - Larbert Station*
- *Rail Bridge Replacement during Blockade*
- *Onshore wind farm design and development*

Flooding, Water & Hydraulics

- *Flooding Problems: Getting the Ground Investigation Right*
- *Water of Leith Flood Prevention Scheme in Edinburgh*
- *Hydro Intake Dam Design*
- *The Drawdown of Craigmaddie Reservoir*
- *Flood Alleviation - Identifying 'The Best' Solution*

Renovation, Refurbishment & Repairs

- *Renovation of the Royal Commonwealth Pool Edinburgh*
- *Refurbishment of Cathedral Street Bridge: Glasgow*
- *Fort Charlotte Perimeter Wall Stabilisation*
- *University of Strathclyde Business School- Understanding Refurbishments and Extensions*
- *The principles/ethos of conservation engineering*

Structural Engineering

- *Offshore Wind Turbine Substructure design*
- *The Design of Critical Components on a Suspension Bridge*
- *Design Optioneering for a Structural Frame*
- *Structural Frame @ the Forfar Community Campus*
- *M&E Services & Structural Frames @ Southern General Hospital*
- *Structural Engineers Register*
- *Concept Design Issues-Glasgow City College Campus*
- *Trends in office design*
- *Bridging the Gap*
- *Constructability Options for Ground Floor slabs*
- *Constructing the Civil Engineering works on a Wind Farm Project*
- *Selection and assessment of a Wind Farm*
- *Design Issues in Bridge*
- *Structural Engineers, Buildability and Architects*
- *Arran Distillery – Problems with Engineering the Water of Life*

Project Management

- *Using CESMM4 on a Bridge Replacement Project*
- *A9 Dualling-Stakeholder Management*
- *Risk - its Assessment and Management*
- *Designing in Buildability & Safety at Eaglesham STW*
- *Pursuing Business Opportunities in Construction – Risk*
- *Health & Safety on a Megaproject (Queensferry Crossing)*
- *Health & Safety Issues in Contracting*
- *Practicalities of delivering the A9 by 2025 while ensuring Value for Money*
- *Costing the Borders Railway Project*
- *H&S Risks and Solutions in Nuclear New Build*
- *Problems & Solutions in Construction Site Logistics*
- *Commercial Management: A Contractors Perspective*
- *Contractor Issues: Cuningar Loop Footbridge*
- *Understanding Client issues during Briefing*

Marine / Docks

- *Cofferdams at Rosyth CVF Infrastructure Upgrade*
- *Structural Aspects Related to the Installation of Manifolds in the North Sea*
- *Civil and Structural Infrastructure of onshore wind farms*
- *Environmental Challenges in Marines Structures*
- *Pier Design on West Coast of Scotland*
- *Design of a New Dock*

Table 1: CE4R Workshops 2012-2018 (n=67)