Education for collaboration in construction: challenges for universities and institutions

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John Connaughton

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Introduction

Construction industries around the world are frequently characterised by generally poor performance across key processes of design development, coordination, management and construction leading to projects that are late-running, over-budget and poorly built. Factors implicated in this include: the organisational and technical complexity of construction projects; disciplinary fragmentation in design and construction; and commercial barriers to effective joined-up working between the parties involved. Improving collaborative working among construction participants as a way of tackling these problems has attracted the attention of scholars for some time (see, for example, Xue *et al*. 2010; Monson *et al*. 2015). Industry-based practitioners have also joined calls for more collaborative working (Morrell 2015; Farmer 2016). In spite of this, and of further arguments that improving collaboration will contribute to more durable behaviour change that will benefit construction as a whole in the long term (Smyth and Pryke 2008; Sunding and Ekholm 2015), achieving more collaborative design and construction processes is still an elusive goal. Questions about how those involved in construction projects can work more effectively together to improve outcomes (Gottlieb and Haugbolle 2013) remain broadly unanswered.

Why is this? It is possible to suggest a range of potential causes across a variety of different perspectives and levels. Professional institutions, focused primarily on the development of their specific, mono-disciplines of architecture, engineering, construction and management, and their role in safeguarding their members' interests do not naturally see improved collaboration as their central concern (Foxell 2019; Morrell 2015). Construction businesses, drawing on lengthy industrial traditions and working within an extensive apparatus of regulation, contracts, processes and procedures that essentially enshrine these institutional divisions do not generally cope well with innovation and change (Reichstein *et al*. 2005) and have little incentive to do so. The public, including the industry's clients, may have little direct interest in collaboration between professional disciplines either. This is arguably because they rely heavily on the professional knowledge in discipline-specific areas to safeguard their interests, and their scope for redress in cases of failure is formed out of sharp distinctions between them (e.g. Lee *et al*. 2020). And construction education, which to a large extent mirrors these wider institutional and societal structures and arrangements, is also implicated. A key criticism is that higher education prepares graduate construction professionals for a life of mono-disciplinary practice that effectively ignores both the need for them to work effectively together with other disciplines and, crucially, the development of skills that would enable them to do so (MacDonald and Mills 2013).

A central dilemma then is that while many associated with construction wish to see more, and more effective collaboration between different disciplines, much of the industry's underlying structures and arrangements are at best not designed with collaboration in mind and, worse, may present significant obstacles to achieving it. Within such context, this chapter focuses on understanding the current and potential contribution that construction education at tertiary/professional level can make in supporting collaboration. To help do that, it will be argued that an important and frequently overlooked challenge to improving collaboration lies in the nature of what collaboration

actually is, and a lack of clarity over what work it involves. So before turning to an examination of the role of construction education, attention turns first of all to concepts and practices of collaboration.

What is collaboration, and how is it done?

There is now a somewhat extensive and growing literature on collaboration in the construction domain. At a very general level, collaboration may be viewed as a form of collective human action in pursuit of a common goal (Wood and Gray 1991). Beyond that, however, there is less agreement about what is involved, and considerable variety in how it is treated in terms of its foundational concepts, the circumstances or conditions that might influence it, the different forms it takes and its underlying purpose.

Key concepts, principles and conditions

Foundational concepts include trust and mutual respect between participants (Kadefors 2004; Nystrom 2005; Gajendran and Brewer 2012; Hughes *et al*. 2012), openness and effective communication (Gajendran and Brewer 2012), and a willingness of participants to work together allied with 'appropriate' behaviours (Lloyd-Walker *et al*. 2014). Favourable conditions are related to such foundational concepts and include relational attitudes and teamworking quality (Suprapto *et al*, 2016), a mutual understanding of project goals and tasks (Okhuysen and Bechky 2009; Mattessich and Monsey 1992), the absence of a range of inappropriate cultural 'barriers' (Mollaoglu *et al*. 2015), and often the presence of a 'convenor' (Wood and Gray 1991) to steer and manage the collaborative endeavour. In terms of the forms that construction collaboration may take, work tends to focus on a wide range of organisational and contractual project arrangements, including partnering, alliancing, joint ventures and networking that are considered to fall within what Hughes *et al*. (2012: 355) describe as an 'umbrella' term of collaboration. In a meta-analysis, London and Pablo (2017: 555-558) draw elements of work on collaboration together and characterise dominant portrayals in mainstream approaches as involving a human activity, led by a convenor and focused on achieving a common goal, seeking integration, accompanied by formal arrangements and 'structures', and taking place in an external environment.

What is collaboration for?

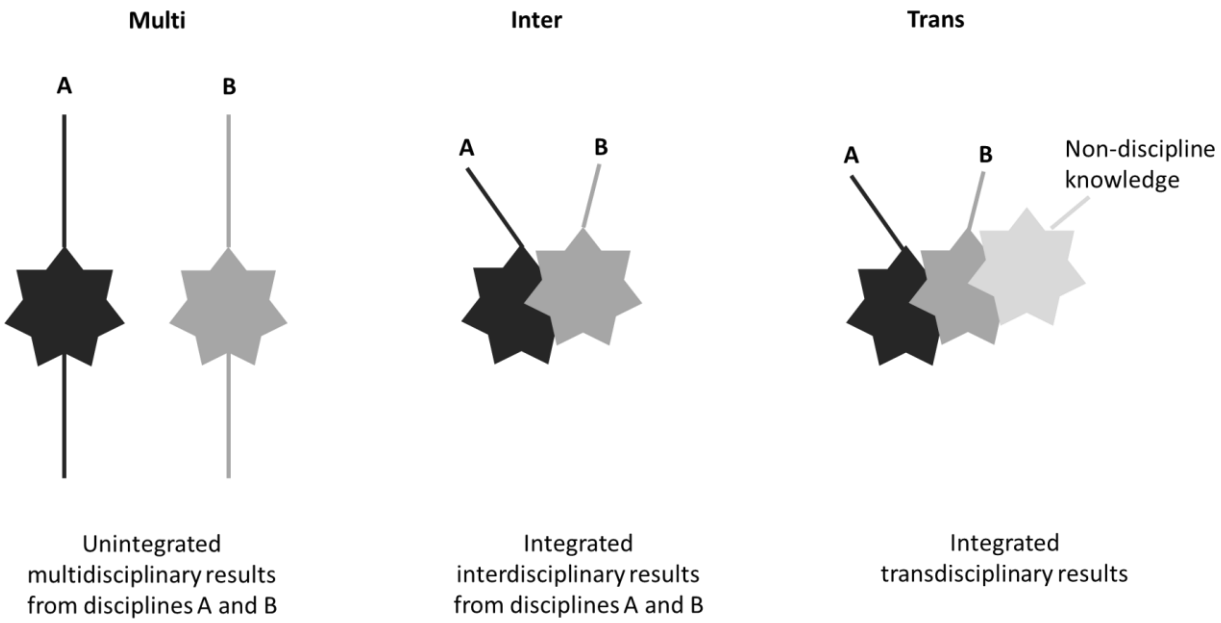
Such contributions are of course important in helping to understand the conditions for collaborative working and how they might be formalised in project contractual arrangements. Indeed, they may be seen as directed at overcoming the kind of institutional and commercial obstacles discussed earlier. But they say little about why construction professionals should collaborate (what it is for) nor, more particularly, what collaboration practice actually involves. These questions matter for those concerned with construction education and the challenge of preparing graduates for a future of collaborative working during their professional lives. And here the question of what it is for seems crucial to understanding what collaboration might entail in the day-to-day work of project life – who works with whom; in what ways; and towards what ends? Yet such questions are not always explicit in much of the collaboration literature. Instead, the core purpose of collaboration in particular is often taken as self-evident: construction is a complex process requiring the input of different disciplines, so improved collaboration between them will improve the process. But is that enough? Is collaboration simply about improving process and efficiency, or might it be more to do with improving outcomes and effectiveness, or indeed both? For Hughes *et al*. (2012), for example, 'desirable aspects' of collaboration may include reducing waste and improving efficiency and profit for those involved. But for Schottle *et al.* (2014), collaboration is about more than this: it is a way of achieving commonly agreed project goals through a joint enterprise in which participants solve problems together and may even share in the risk and reward of doing so.

What does collaboration involve?

And what do such different notions of what collaboration is for imply for what it involves and how it might be done? Perhaps because the purpose is not always clearly defined, the different ways in which collaboration is conceptualised and described are not so clearly distinguished either. For some, collaboration is a general term for working together, and is used synonymously with other terms including coordination and cooperation, as in Bygballe *et al*. (2016), for example, to help explain the quality and intensity of relationships between project participants. But coordination is arguably different, involving more of a temporal or organisational ordering of the respective inputs of project participants working together (e.g. Bechky 2006; Okhuysen and Bechky 2009; Boudeau 2013 and, indeed, in Bygballe *et al*. 2016). And according to Schottle *et al.* (2014), such coordinating activity requires less integration of the respective contributions of different disciplines than a more active form of collaboration that is about creating a shared enterprise between them. Similarly, cooperation may cover situations where disciplines contribute their respective inputs but stop short of an active sharing of them, retaining ownership of their contributions alongside their professional independence. Again, Schottle *et al*. (2014; 1273-5) distinguish this from what they consider to be collaboration, the latter involving participants surrendering some of their independence in sharing responsibility for problem solving in the joint enterprise they create and in which they share the risk and reward of resultant outcomes.

In a sense, then, these different concepts of working together – of coordination, cooperation and collaboration – could potentially represent different degrees or intensities of collaborative working, reflecting also the extent to which contributions from individual participants are integrated. But, as noted, they are not always clearly delineated in treatments of collaboration. A similar and potentially useful categorisation is available from work in the area of collaborative research that takes a disciplinary perspective. Klaassen (2018), drawing on Menken and Keestra (2016) highlights distinctions between multidisciplinary, interdisciplinary and transdisciplinary working in terms of a simple and gradual scale to help describe how knowledge from different sources is progressively integrated. Their scheme is illustrated in Figure 1. At the first level, termed multidisciplinary working (Multi), disciplinary contributions are unintegrated. Each discipline contributes a piece of the jigsaw, so to speak, which is largely unaltered in the final outcome and sits alongside other disciplinary inputs. The result is a series of parallel visions of the 'problem area' (or, in construction project terms, the project aims and potential solutions) from different disciplinary perspectives. By contrast, at a higher level of integration and collaborative working (termed interdisciplinary working – Inter), the different disciplinary contributions become more integrated in a synergistic way, developing shared problem solutions (Schottle *et al* 2014) that go beyond the primarily additive outcomes of multidisciplinary working. And finally, transdisciplinary working (Trans) involves stakeholder contributions outside of the normal disciplinary groupings in a search for innovative solutions.

Figure x.1 Levels of integration in different forms of collaborative working



Source: After Klaassen, 2018; Menken and Keestra, 2016

Construction, with its often complex requirements and site-specific contexts that mean solutions are not always known in advance, is particularly amenable to interdisciplinary problem solving. In recent years a focus on the challenges presented by the need for improved sustainability performance requiring novel, inter- and transdisciplinary solutions has brought this into sharp focus (Hill and Lorenz 2011; Pero *et al* 2017). Yet, in work on collaboration, the distinction is not always clearly made and, as with the interchangeable use of concepts such as coordination, cooperation and collaboration, the implications for what interdisciplinary and transdisciplinary working might mean for construction are not always explicitly recognised or explored.

So, perhaps because of this, little attention is paid to understanding the practices of collaboration and how people work together in different ways, particularly in the kind of interdisciplinary working that involves the sharing and integration of knowledge and decision inputs to create novel, shared solutions. Rather, the focus of a good deal of the literature seems to be more on understanding and developing the *conditions* – contractual and otherwise – favourable to collaboration. And because of this, there is an underlying assumption that really all that is needed to unlock the assumed innate potential of professionals to collaborate are the right conditions to enable them to work together. But what of the actual doing of collaboration, especially in interdisciplinary working which suggests that professionals work across disciplinary boundaries and, indeed, may share responsibility for outcomes? If they already know how to do this, where does this knowledge come from?

Education for collaboration in construction– an overview

Collaboration in degree-level construction education

Education of construction professionals at undergraduate level tends to be delivered primarily through degree programs in mono-disciplinary schools and departments focusing on architecture, urban planning and a range of engineering, construction management and surveying disciplines (Morell 2015; MacLaren *et al*. 2017). Such programs generally offer a route to membership of

professional institutions and are accredited by them. While MacLaren *et al*. (2017), for example, note how some UK institutions require degree programs to take account of the need for skills in aspects of collaboration, including teamworking and a knowledge of different disciplinary roles, a brief review of the accreditation requirements of the main UK institutions suggests that such requirements are not extensive – see summary in Table 1. Indeed, in so far as they acknowledge the need for collaboration at all, they tend to focus mainly on developing an *awareness* of the role and contributions of other disciplines rather than developing particular collaboration skills and knowledge, especially for working at the interdisciplinary level.

Table x.1 Accreditation requirements of the major UK institutions for undergraduate degrees: the extent to which they include explicit criteria relating to collaboration

RIBA (RIBA, 2014)	Very little on collaboration in the General Criteria and Graduate Attributes at Part 1 and Part 2, apart from General Criteria relating to understanding of 'the role of the architect within the design team' and a knowledge of 'professional inter-relationships in … architectural projects' as well as 'contributions of architects and co-professionals to the formulation of the brief' (2014; 59-61).
RICS (RICS, 2018)	RICS requirements are somewhat complicated by the range of surveying disciplines covered and the different 'pathways' to membership. Mandatory requirements in the 'Competencies' guide cover 'Diversity inclusion and teamworking' but do not explicitly cover collaboration (2018; 17). Competencies also include leadership and managing people in relation to senior roles (2018; 20-21) but not specifically in relation to collaboration.
CIOB (CIOB, 2018)	CIOB acknowledges the need to 'recognize the collaborative linkages and interdisciplinary relationships' and to 'evaluate the challenges of working in a collaborative environment', but emphasis more on teamworking and conflict resolution in terms of skills required for working with others (2018: 13-14, 18).
Engineering (Engineering Council, 2014)	Engineering requirements are somewhat complicated by the range of engineering disciplines and institutions involved. In the UK the Engineering Council sets the overall accreditation requirements for higher education engineering programs. In these requirements the emphasis is mainly on technical knowledge, competence and skill development in science and engineering disciplines. There are some requirements in the 'practice' element for an 'Awareness of team roles and the ability to work as a member of an engineering team' and a recognition of the personal responsibility required for teamworking (2014; e.g. 14), but no explicit requirement for interdisciplinary collaboration.

And while the relative lack of emphasis on collaboration in institutions' accreditation requirements perhaps underpins the reluctance of universities to focus on it, there are other factors at work. Morrell (2015), for example, speaks about a fragmented and siloed construction education process, observing that many schools and universities lack one or another of the disciplines necessary to establish multi-disciplinary faculties and approaches. Further, for those that have them, single-discipline departments can be isolated from each other by university structures (Morrell 2015: 59). MacLaren *et al*. (2017; 182) highlight higher education funding structures that encourage academic staff to develop deep domain expertise at the expense of competence – and an interest – in cross-discipline collaboration. In earlier work, MacDonald and Mills (2013) also argued that such specialist staff have little incentive to shed their hard-won expertise and associated teaching habits and material developed over many years. Additionally, they point to a lack of compensation across faculties for staff involvement in cross-disciplinary working, as well as pressures created by growing class sizes (particularly in Australia, where many academics face minimum class sizes of 80) that

present difficult challenges for the development of multi-disciplinary programs (MacDonald and Mills 2013: 97-98).

But this is not to say that tertiary education across construction disciplines has ignored the need for collaboration in construction project teams. Far from it. Indeed, construction degree programs have long recognised that construction professionals need to work together – Selman and Westcott (2005), for example, describe how module design in built environment courses at the University of the West of England has adopted an 'interdisciplinary philosophy' since the early 1990s. And degree programs typically include elements designed to support the development of what Holland *et al.* (2010) describe as 'T-shaped people': professionals that have deep knowledge of their own discipline and a broad understanding of the roles and responsibilities of others in the team. Many ideas have been proposed to address this in which, for example, construction courses could contain common years of study across different disciplines, as well as common subject modules (e.g. Manthe and Smallwood 2007). While this may seem to be a (albeit partial) response to institutional requirements for *knowledge* of related professional disciplines, it does not explicitly address the question of the *ability* required to collaborate actively with them. However, more recent ideas associated with learning in groups (frequently referred to as 'collaborative learning') have sought to shift the emphasis towards the latter.

Education for collaboration – the importance of learning in groups

Ideas of learning in groups are not particularly new in tertiary education. Davidson and Major (2014), for example, chart a growing interest in group-based learning since the 1960s, with theoretical origins in social interdependence theory (see Johnson and Johnson, 1994; 2009) and considerable, if at times mixed, empirical evidence supporting its beneficial use (e.g. Springer *et al*. 1999; Smits *et al.* 2002). Indeed, such has been the extent of academic interest that developments in this broad area have led to a myriad terms describing a range of approaches to learning in groups, including small-group learning, collaborative learning, cooperative learning, problem-based learning, team-based learning and a variety of other terms (Davidson and Major, 2014: 9-10). And while this descriptive terminology varies considerably, so also do ideas about the purpose of group-based learning, ranging from claimed benefits in long-term knowledge retention to the development of skills necessary for future collaboration.

In a helpful general categorisation, Davidson and Major (2014) distinguish three dominant forms of learning in groups: cooperative, problem-based and collaborative learning, each having different theoretical underpinnings and assumptions. In this broad scheme, cooperative learning covers a wide range of approaches concerned with students working in groups in which they communicate with and help each other to complete learning tasks (Davidson 2002; Leite 2016). Problem-based learning puts the task or 'problem' – often presented as a 'real world', messy problem – centre stage to provide both the context and stimulus for the acquisition of knowledge and the development of problem-solving skills (Savery 2006). Collaborative learning departs somewhat from these approaches in its focus on the co-creation of knowledge by students and teachers working together. This essentially interpretivist approach (Bruffee 1993 in Davidson and Major 2014: 20-21) can be task- or problem-focused, the emphasis typically falling on the creation of novel solutions or products, and not simply the teacher's version of them.

A further element may be a requirement for students to take responsibility for their learning and what they create out of the collaborative endeavour (Bruffee 1993). While these broad distinctions become blurred in application and development, they help with understanding both the purpose of learning in groups and what this may involve. As with the concepts of collaborative working illustrated in Figure 1, they also suggest a broad (albeit crude) 'scale' for understanding the extent of

interdisciplinary collaboration that might be involved. With this in mind, some approaches to learning in groups in construction education will now be briefly discussed. While a comprehensive review is beyond the scope of this chapter, the intention is to illustrate the range of provision, identify some of the more common elements and discuss the extent to which different approaches may address particular concepts of collaborative working and learning discussed earlier.

How is education for collaboration in construction done? – some examples

Construction, with its focus on one-off projects and preoccupation with teamworking, provides considerable opportunity for cooperation and problem-based learning approaches. In the construction domain, Chan and Sher (2014), for example, distinguish a particular form of problem-based learning as project-based learning, with the problem area in the latter more focused on the development of workable, project solutions than the potentially more open-ended outcomes of the former. Their interest is in improving students' teamworking and interpersonal skills and, based on a survey of students' learning preferences, they argue that such skills may be improved when students from different disciplines work together on multi-disciplinary, project-based assignments. Indeed, such project- or case-based approaches now feature prominently in construction education, particularly when geared towards collaborative working. The Live Projects Network, for example, provides a resource base of projects intended to provide learning contexts that 'extend the institutional confines of the design studio'[i]. While not exclusively focused on interdisciplinary collaboration, the Network provides a sense of the diversity of approaches to the use of project-based learning, particularly in relation to developing participatory approaches to the design of buildings and urban spaces (see also Harris and Widder 2014, for example).

In a review of approaches to interdisciplinary construction education across four UK Higher Education Institutions (HEIs), MacLaren *et al.* (2017) argue that it is not enough to try to teach teamworking in interdisciplinary groups; rather, students need to experience the collaborative environment in multidisciplinary project settings. Such experiential learning has long been a feature of construction education, particularly in relation to site-based workers (Floe 2019) and with some application in more professional disciplines also (Forster *et al.* 2017). The more immediate question here, however, is the extent to which such learning is focused on particular concepts of collaboration. MacLaren *et al.* observe that common features of seven group-learning case studies examined include the implicit adoption of a working definition of collaboration from Wood and Gray (1991) that describes a generic form of working together (2017: 183, 195-7). This is despite the focus of many of the project-based scenarios adopted being on the development of innovative solutions rather than more conventional responses to project/study briefs that might, perhaps, have required a more purposefully creative, interdisciplinary form of collaboration described, for example, by Schottle *et al.* (2014).

Of course, different project settings arguably provide different opportunities for group learning with a focus on collaboration. The particular context of sustainable design, also requiring novel solutions to interdisciplinary challenges, has featured explicitly in group-based learning approaches. This can, according to Brncich *et al.* (2011: 23) provide 'an effective framework for sustainable design and construction education'. In the case study featured, they focus on some of the perceived benefits to students of the group approach in raising their awareness of the roles of other disciplines and the importance of communication in team working, as well as learning about important technical and performance aspects of sustainable design. Valdes-Vasquez and Clevenger (2015) also use a sustainable building project in an approach to developing interdisciplinary classroom activity designed to promote more specific collaborative working skills such as communication, conflict resolution, decision-making and problem solving. Their interest is in collaboration that is focused on

the development of improved design solutions: 'building delivery is not produced from one person's thinking process; rather, it is the result of the technical collective knowledge from different disciplines' (Valdes-Vasquez and Clevenger 2015: 81).

The potential of computer-based developments to transform professional working is currently the subject of considerable debate and enquiry (Susskind and Susskind 2015). In construction, the particular adoption of Building Information Modelling (BIM) across its many guises to support more integrated, collaborative working has also been the focus of a number of approaches to group learning. MacDonald and Mills (2013), for example, suggest that university curricula have not developed sufficiently rapidly to respond to growing requirements for collaborative working capabilities in response to developments such as Integrated Project Delivery (IPD). They propose a new framework that seeks to integrate principles of collaboration with BIM technologies through a focus on the development of 'both technical (I.T and discipline-specific) and interpersonal (collaborative and teamwork) skills' (MacDonald and Mills 2013: 99). To support this they advocate revisions to professional institutions' accreditation requirements so they address more collaborative working skills.

Zhao *et al.* (2015) focus rather more on the potential of BIM to provide a learning environment for collaborative skill development and working. They characterise a good deal of BIM coverage in university curricula in the USA as being concerned with technology application, lacking a focus on collaborative working. They argue that equipping students with BIM knowledge is not all that is needed to meet industry's needs for skilled construction professionals. Using a simulation of 'real world' working conditions requiring students to work within a BIM environment, they found that students from different engineering and construction disciplines felt they improved their collaborative workings skills in communication, coordination, cooperation and goal setting (Zhao *et al.* 2105; 114-7).

Comiskey *et al.* (2017), while pointing to the relative immaturity of BIM-focused material in degree programs in the UK and Ireland, focus on the use of data sharing platforms to support collaborative learning in project-based activity among students from different disciplines. While the potential for team-based problem solving to help those involved appreciate the contributions others can make is recognised, learning outcomes seem rather more focused on technology application and use than they are on the development of collaborating skill. Similarly, Vassigh *et al.* (2020) examine the role of virtual- and augmented-reality (AR and VR) technologies to simulate 'real world' project conditions for collaborative learning approaches in which students across different construction disciplines work together. Using a sustainable building design scenario, their focus – as with Comiskey *et al.* (2017) – is as much on the potential for learning collaboratively about the technical and performance aspects of the sustainable design challenge as it is about learning how to engage in more collaborative working. Nonetheless, the use of the AR and VR technologies was seen to promote group discussion and interaction, and a generally positive student attitude towards working together.

Education for collaboration in construction – some challenges and dilemmas

The foregoing vignettes of group-based learning approaches in construction highlight some important issues for any consideration of the role of tertiary education in supporting collaborative working among construction professionals. First, they provide evidence of significant activity in the development of group-based learning approaches over a number of years to suggest that ongoing criticism that education providers are either ignoring the need for collaborative working or lack the ability to do anything about it is not well-founded. That said, however, approaches to group-based

learning, despite their range and diversity, can hardly be considered mainstream across the broad landscape of construction tertiary education. And further, while many group-based approaches adopt a form of 'project-based' learning (Chan and Sher 2014), there is considerable diversity and, indeed ambiguity in terms of their purpose and the different forms of collaboration they are meant to support. It is not always clear, for example, whether such approaches are intended to enhance core disciplinary knowledge on the one hand, or skill in collaborative working on the other, or indeed both. To put it another way, are they about learning collaboratively or learning to collaborate?

Learning collaboratively or learning to collaborate?

It is possible to distinguish the potential learning outcomes of the kind of group-based learning discussed above in two important ways. In the first of these, students learn more *about their disciplinary or topic domain* and related areas, and at the same time develop a better *awareness of others' inputs and capabilities* (Manthe and Smallwood 2007; Brncich *et al.* 2011; Comiskey *et al.* 2017). In other words, learning outcomes are primarily single-discipline focused. While students learn from each other alongside their peers from other disciplines, they exchange information and knowledge in a primarily cooperative learning activity that is focused on enhancing their understanding of the role and context of their own discipline.

By contrast, learning outcomes may be focused more on *how to work collaboratively*. In this approach the focus is more on the development of skills in aspects of collaborative working including communication, the development of interpersonal working relationships, and leadership (McDonald and Mills 2013; Chan and Sher 2014; MacLaren *et al.* 2017; Vassigh *et al.* 2020). In these approaches students are typically engaged in more of a joint endeavour around the problem area as part of a mainly collaborative activity geared towards developing additional know-how in joint problem solving and in working together.

These outcomes are not mutually exclusive and may not always be so easily distinguished either. However, in terms of the collaborative working scheme outlined earlier (see Fig. 1), learning to work *alongside* each other may be distinguished from learning to work *with* each other. In these terms, the former may be characterised by a primarily multidisciplinary *exchange* of information between participants, whereas the latter is more concerned with he *co-creation* of knowledge as participants collaborate with each other in a joint enterprise. The problem, when these outcomes are not clearly distinguished, is that what seems to matter more is the act of bringing students from different disciplines together in the belief that this, of itself, is sufficient to open up a range of collaborative learning outcomes. It is as if – as reflected in a good deal of the collaboration literature briefly reviewed above – the presence of appropriate conditions (here in the form of multidisciplinary, group-based learning settings focused on project 'problems') is all that is needed to enable the innate collaborative abilities of students to come to the fore. And in these terms, opportunities for both the development of disciplinary knowledge *and*, where required, new collaborative capability are expected to arise without having to pay specific attention to either of them.

But some important questions arise here. One concerns skills. By mentioning so-called collaborative skills such as communication and relationship development, many approaches to group-based learning seem to take for granted what is involved in collaboration, without explicating what these skills involve nor how they might support and help participants to engage effectively in collaborative working. And this obscures a further question, which is about the nature of the collaborative endeavour that is envisaged and may be desired. In terms of the collaborative scheme shown in Fig. 1, is the idea to help prepare students for a future of multidisciplinary working, or of inter-/transdisciplinary collaboration? For if these distinctions are significant, surely they also matter in terms of the skill requirements of potential collaborators. These questions go to the core of what

the role of tertiary education in this context might be and raise a number of challenges and indeed dilemmas for providers in mainstreaming collaborative approaches that will now be discussed.

Can collaboration be taught?

Many of the approaches to group-based learning highlighted above draw on theories of collaborative learning to help explain and set them in context. Problem-based learning, with its early origins in the teaching of medicine and other healthcare disciplines (Savin-Baden and Major 2004) provides the basis for a number of approaches (Chan and Sher 2014; Vassigh *et al.* 2020). Group-based learning more generally has somewhat deeper origins (Dewey 1938) that are reflected in many contemporary approaches. These include a number of the construction-focused and group-based initiatives described by MacLaren *et al.* (2017) that emphasise the participatory nature of the problem/project settings, and recognise the educational value as lying in the process rather than the output. Other approaches align with recognised learning frameworks and taxonomies, such as 'Bloom's taxonomy of learning' (Bloom *et al.* 1956) that is adopted by MacDonald and Mills (2013: 99) into a framework designed to support academics in the incorporation of collaborative design principles into their curricula. But few, it would seem, are informed to a similar degree, if at all, by theories of collaborative working, or an explication of associated collaborative working practices.

A challenge, however, is that work on collaboration in construction in particular is at an early stage in its development and, as argued above, there is little established theory, nor much consensus on what collaborative work actually involves either. And in its absence, one problem is that, as noted briefly above, work on collaborative learning tends to cover a range of aspects *perceived* to support collaborative working – good communication, the development of interpersonal relationships, teamwork, conflict resolution, leadership, and a host of others – but without necessarily highlighting any of them or unravelling and explicating their respective roles in collaborative work. What is needed therefore is more scholarly work focused on what different forms of collaboration involve and what differences between them mean so that the knowledge and skill needed in their performance can be understood and developed by those providing the education intended to support them. While the need may seem obvious, it has tended to be ignored in work on group-based learning in construction and, for such work to progress, needs to be brought more fully into thinking about collaborative learning – and working – in this sector.

A further challenge, particularly in relation to the kind of interdisciplinary collaboration discussed throughout, is to understand not only how collaboration works, but what the implications of working *across* disciplinary boundaries might be, for professional institutions, businesses and individual professionals. Questions of how normal professional boundaries (what Abbott 1988 [at 88-90] refers to as 'jurisdictions') may need to be relaxed or even reconfigured. These challenge the relevance and durability of traditional jurisdictions of professional 'practice' and the role of institutions in developing and protecting them. The role of construction businesses, many of which are organised for the delivery of professional services along disciplinary lines and are regulated by institutions (Connaughton and Meikle 2013) is also relevant. Questions of professional identity, amongst other things, arise for individual professionals also. While a more detailed exploration of these issues is beyond the scope of this chapter, they are germane to a consideration of how professional knowledge and competence is organised and managed, and traded in the construction marketplace. In this context, the extent to which interdisciplinary collaboration may require new competencies, and who might be responsible for providing them raises an enduring question: is it about education or training?

Key dilemmas for education

Tertiary educators regularly confront questions of whether their role is the production of employable 'job-ready' graduates or whether they are helping to prepare young people for a longer-term lifetime of learning in a 'learning to learn' approach (for a discussion see Oliver 2013). Many argue that they are primarily engaged in the latter, distinguishing education from training. And yet, when it comes to thinking about working collaboratively in construction, the focus is on a largely experiential approach that would seem to eschew thinking about understanding collaboration from a more abstract and theoretical perspective in favour of an emphasis on learning how to do it by experiencing the doing of it. Across many of the examples of group-learning discussed, it is possible to see a sort of 'dominant logic' in which, according to MacLaren *et al.* (2017), the preferred means of helping students understand the demands of collaborative work is self-evidently to get them to experience it in simulated multidisciplinary project settings. An irony in this, of course, is that it would seem to place educators more in the practice and training domains than in the educational one, at least in terms of the broad distinctions outlined above. Regardless, the more fundamental questions are about what such simulations of project life have to offer for learning outcomes and for preparing graduates for working collaboratively and these questions are ultimately about the nature and purpose of the collaborative enterprise in which graduates might be involved during their working lives.

While there seems to be wide consensus that project-based simulation is valuable and enhances the learning experience, must collaborative learning always be done by mimicking what is happening in 'real' project life? In relation to distinctions between multidisciplinary and interdisciplinary working, for example, to what extent can simulations of typical project settings prepare students for a new and different version of the project life they might encounter in future that is more open to active collaboration involving cross-disciplinary working and responsibility sharing? Must future practice be rehearsed as something knowable that will be encountered, or can it imagined and co-created as new sets of activities and future practices? Addressing these latter questions, and paying attention to the need for further work on the role and nature of collaborative working, educators could potentially chart a clearer path which is more about teaching to learn rather than practising to do.

Additionally, important questions for educators centre around the relative efficacy of different modes and approaches. Group-learning tends to be premised on a belief that experience of this environment is valuable and improves learning outcomes. And while in general, evidence for the benefits of collaborative learning seems mostly positive (e.g. Laal and Ghodsi 2012; Springer *et al.* 2009) findings are not entirely conclusive (e.g. Wang and Burton 2010). In the construction domain this may be because, as noted above, learning outcomes are not always clearly defined and are, in any event, difficult to assess. While short term knowledge retention and understanding is typically evaluated via examinations and assignments, assessing more longer-term knowledge retention and the development of collaboration skill presents significant challenges.

A number of collaborative learning approaches in the construction domain base evaluation on student surveys undertaken during or immediately following the collaborative learning exercises (Chan and Sher 2014; Valdes-Vasquez and Clevenger 2015; Zhao *et al*. 2015, Comiskey *et al.* 2017; Vassigh *et al*. 2020) that, to varying degrees, rely on students' self-assessment and reported satisfaction. These provide at best somewhat limited indicators of learning efficacy and, in line with additional work to understand the nature of collaborative working identified above, there is a further need to improve understanding of the usefulness and efficacy of different approaches to group-based learning. These could perhaps involve a more longitudinal approach (for an example in

healthcare, see Pollard *et al.* 2004) to collaborative learning across different collaborative settings that would support its consolidation and further development within tertiary curricula.

Some further comments

Some important practical issues also arise in thinking about learning for collaboration and collaborative learning. The idea of 'T-shaped' professionals (Holland *et al.* 2010) that have deep knowledge of their own discipline and a broad understanding of the roles and responsibilities of others does not, on the face of it, present insurmountable challenges for tertiary providers. But given the extent to which many construction degree programs are accredited by professional institutions, and the dominance of core, mono-disciplinary content at the expense of knowledge or skill development in collaborative working (see above, and Table 1), a more practical question arises as to how to fit it all in. A further dilemma for educators is that not all students like collaborative learning – there may be particular cultural preferences across different student cohorts (Li and Campbell 2008), and there is a sense also that some more talented students may feel that less capable colleagues are benefitting at their expense in group-based work and assignments (Ford and Morice 2003). Further, students may encounter collaborative learning opportunities fairly rarely, and thus may feel less comfortable in such an environment than when working within their core discipline, which may create a greater sense of belonging (Vassigh *et al.* 2020).

While such challenges would need to be addressed in the design of group-based learning approaches, the more fundamental question of the relative efficacy of this form of learning opens up a further debate around what it could be used for. The scope is potentially wide and could cover not only a broad range of subjects that are typically taught in single-discipline modules that could be delivered in a more collaborative learning environment, but entire programs as well. Indeed, there is a growing interest in cross-disciplinary courses at both undergraduate and postgraduate level in, for example, architectural engineering in the UK[ii] that provide considerable opportunities for collaborative learning. These would seem to open wider possibilities that go well beyond the provision of a small element of group learning that, at best, allows students some brief, prior experience of their likely future work settings. Instead, providing the majority of learning in a group-based, intentionally cross-disciplinary setting could start to create the sort of 'shared professional identity' among different disciplines that, as Hartenberger *et al.* (2013) argue, not only encourages information-sharing between disciplines, but also more of a sharing and strengthening of collective responsibility for project outcomes.

This then brings some of the questions for institutions identified above – about how generally accepted jurisdictions of professional practice to support interdisciplinary collaboration might need to be reconfigured – into sharper focus. Indeed, the key to the more widespread adoption of interdisciplinary collaboration would seem to lie in joint working between education providers and the professional institutions around an understanding of what it means to be a professional in contemporary construction, and of the benefits of collaborative working. And while there would seem to be considerable work to do here, a starting point could be recognition that, with interdisciplinary collaboration centre stage, what really matters is a shared responsibility to society generally for the outcomes of the design and construction process.

Concluding remarks

This chapter started with an overview of some of the ongoing problems endemic in design and construction processes. Collaboration between design and construction professionals – particularly in terms of inter-and trans-disciplinary collaboration in which different contributions become more integrated in developing shared problem solutions (Schottle *et al.* 2014) – has the potential to

address many of these problems. Interdisciplinary and transdisciplinary collaboration go beyond simple concepts of working together. In particular, the outcomes of such collaboration are ultimately greater than the primarily additive outcomes of multidisciplinary working, focusing more on the creation of novel, shared solutions through the sharing and integration of knowledge and skill. Further, such sharing of intellectual and creative capital can also involve sharing in the responsibility for project outcomes, and it is this that promises considerable transformative potential for construction. The industry's clients can benefit not only from more creative, innovative solutions but from an assurance of collective responsibility that avoids an endless quest for fault if things go wrong. Institutions can support the development of a shared professional identify across professions that may prove attractive to members as well as to potential entrants. Design and construction businesses also gain from working more closely together, sharing in the rewards of success and reducing the risk of failure.

The role of education providers in helping to move working practice towards greater inter- and transdisciplinary collaboration is crucial. For some, a key challenge is for providers to break out of the predominantly monodisciplinary structure of degree-level construction education. And yet many providers have been doing that, and continue to do much in the area of collaborative learning that at the very least recognises some of the realities of construction project life in which disciplines have to work together. What is less clear is the extent to which, if at all, such work is focused explicitly on developing knowledge and skill in the kind of interdisciplinary and transdisciplinary collaboration discussed here. Moreover, such ideas of collaboration are not yet widely adopted in construction practice either, nor are they well understood. But, as noted, their potential to transform how people work together to create innovative and valuable construction outcomes is considerable.

A starting point is needed for considering how tertiary construction education can support more interdisciplinary collaboration among tomorrow's professionals. This lies in developing an improved understanding of collaboration that moves away from thinking that the provision of favourable conditions for collaborative working is all that matters. Certainly, supportive conditions are important to encourage and support working together, but the nature of the collaborative enterprise and the skills needed to engage effectively in it need to be more clearly understood to provide the foundation for improved collaborative learning and, ultimately, working. This is a key role for the research and education capabilities within tertiary education providers.

An important challenge here is that interdisciplinary collaboration is not particularly easy to pinpoint or explicate. Occurring at and between disciplinary boundaries in what Klaassen (2018:2) describes as a 'third space' in which the meeting of different perspectives stimulates co-construction of new knowledge, learning and innovation, it remains an elusive and somewhat aspirational ideal of collaborative working. And it raises challenges for institutions also, not least for what it means for established jurisdictions of disciplinary knowledge and normal professional practice boundaries. The potential, therefore – and indeed the need – for educators *and* institutions to work together is considerable. It can be achieved by focusing more on understanding and developing collaborative approaches to building design and construction in which problems might be resolved more effectively and those involved may share in the responsibility for the outcomes.

In these terms the scale of the challenge of unlocking the collaborative potential of construction professionals working creatively and responsibly in a joint endeavour is not insignificant. But neither are the potential benefits. Indeed, developing more creative and rewarding working environments for those who work in construction as well as better outcomes for those in wider society who depend on it surely provides a compelling case for concerted action by educators and institutions.

Such joint, collaborative endeavour is required to start to solve the conundrum of what collaboration is needed and how education can support it.

Notes

[i] https://liveprojectsnetwork.org/

[ii] For a selection, see one of the UK's course selector tools at https://www.whatuni.com/degree-courses/search?subject=architectural-engineering

References and further reading

Abbott, A. (1988) *The System of Professions: An Essay on the Division of Expert Labor* (Chicago: University of Chicago Press).

Bechky, B.A., (2006) 'Gaffers, gofers, and grips: role-based coordination in temporary organizations'. *Organization Science*, 17 (1), 3–21.

Bloom, B.S., Englehart, M.D., Furst, E.J., Hill, W.H., Krathwohl, D.R. (1956) *The Taxonomy of Educational Objectives, The Classification of Educational Goals, Handbook I: Cognitive Domain* (New York: David McKay Company).

Boudeau, C. (2013) Design team meetings and the coordination of expertise: the roof garden of a hospital. *Construction Management and Economics*, **31** (1), 78-89.

Brncich, A., Shane, J.S., Strong. K.C., and Passe, U. (2011) Using Integrated Student Teams to Advance Education in Sustainable Design and Construction. *International Journal of Construction Education and Research*, **7** (1), 22-40. doi.org/10.1080/15578771.2010.512034

Bruffee, K. (1993) *Collaborative learning: Higher education, interdependence, and the authority of knowledge* (Baltimore: The Johns Hopkins University Press).

Bygballe, L.E., Sward, A.R. & Vaagaasar, A.L. (2016) 'Coordinating in construction projects and the emergence of synchronized readiness'. *International Journal of Project Management*, 34 (2016), 1479-1492.

Chan, T.W. C. and Sher, W. (2014) Exploring AEC education through collaborative learning. *Engineering, Construction and Architectural Management*, **21** (5), 532-550. doi.org/10.1108/ECAM-04-2013-0036

CIOB (2018) *CIOB Undergraduate Education Framework*. (Bracknell: Chartered Institute of Building).

Comiskey, D., McKane, M., O'Shea, E., Hughes, J., McNiff, S. and Eadie, R. (2016) Collaborative & Multidiscipline Working - From Theory to Practice in 48 Hours: A case study from BIM region Northern Ireland. *International Journal of 3-D Information Modeling*, **5** (2), 55–71. doi.org/10.4018/IJ3DIM.2016040104

Comiskey, D., McKane, M., Jaffrey, A., Wilson, P. and Mordue, D. (2017) An analysis of data sharing platforms in multidisciplinary education. *Architectural Engineering and Design Management*, **13** (4), 244-261. doi.org/10.1080/17452007.2017.1306483

Connaughton, J. and Meikle, J. (2013) The changing nature of UK construction professional service firms. *Building Research & Information*, **41** (1), 95-109. doi.org/10.1080/09613218.2013.742366

Cooper-Cooke, B., Sutrisna, M., and Olatunji, O.A (2020) Innovation in the globalised world: educating future building professionals. *Construction Economics and Building*, **20** (3), 56-61. doi.org/10.5130/AJCEB.v20i3.7410

Davidson, N. (2002) Cooperative and collaborative learning: An integrative perspective. In: Thousand, J., Villa, R. and Nevin, A. (eds.) *Creativity and collaborative learning: A practical guide for empowering teachers and students*, 2nd Edition. (Baltimore: Brookes).

Davidson, N. and Major, C. H. (2014) Boundary crossings: Cooperative learning, collaborative learning, and problem-based learning. *Journal on Excellence in College Teaching*, **25** (3&4), 7-55.

Dewey, J. (1938) *Experience and education* (New York, NY: Kappa Delta Pi - republished by Collier, 1963).

Engineering Council (2014) *The Accreditation of Higher Education Programs. UK Standard for Professional Engineering Competence* (3rd Edition). (London: Engineering Council). Retrieved from http://www.engc.org.uk/ahep.aspx

Farmer, M. (2016) *The Farmer Review of the UK Construction Labour Model: Modernise or Die*, (London: Construction Leadership Council).

Foxell, S. (2019) *Professionalism for the Built Environment*. (London: Routledge).

Floe, C. (2019) *Best practice in experiential learning: Evidence review for the Construction Industry Training Board*. (London: Traverse). Retrieved from: www.citb.co.uk/global/funding/best%20practice%20in%20experiential%20learning%20-final.pdf

Ford, M. and Morice, J. (2003) How fair are group assignments? A survey of students and faculty and a modest proposal. *Journal of Information Technology Education*, **2** (1), 367-378.

Forster, A. M., Pilcher, N., Tennant, S., Murray, M., Craig, N., and Copping, A. (2017) The fall and rise of experiential construction and engineering education: decoupling and recoupling practice and theory. *Higher Education Pedagogies*, **2** (1), 79-100.

Froyd, J. E., Wankat, P. C., and Smith, K. A. (2012) Five major shifts in 100 years of engineering education. *Proceedings of the IEE, Vol. 100, Special Centennial Issue,* 1344-1360, 13 May 2012, doi.org10.1109/JPROC.2012.2190167.

Gajendran, T. and Brewer, G. (2012) Collaboration in public sector projects: unearthing the contextual challenges posed in project environments. *Engineering Project Organization Journal*, **2** (3), 112-126.

Gottlieb, S.C. and Haugbolle, K. (2013) Contradictions and collaboration: partnering in-between systems of production, values and interests. *Construction Management and Economics*, **31** (2), 119-134.

Harriss, H. and Widder, L. (eds.) (2014) *Architecture live projects: Pedagogy into practice*. (Abingdon: Routledge).

Hartenberger, U., Lorenz, D. and Lützkendorf, D. (2013) 'A shared built environment professional identity through education and training. *Building Research & Information*, **41** (1), 60-76. doi.org/10.1080/09613218.2013.736202

Hill, S. and Lorenz, D. (2011) Rethinking professionalism: guardianship of land and resources. *Building Research & Information*, **39** (3), 314–319.

Holland, R., Messner, J., Parfitt, K., Poerschke, U., Pihlak, M. and Solnosky, R., (2010) Integrated Design Courses Using BIM as the Technology Platform. *National Institute of Building Sciences, Annual Meeting of EcoBuild America Conference*, December 7, 2010, Washington, D.C.

Hughes, D., Williams, T. and Ren, Z. (2012) Differing perspectives on collaboration in construction. *Construction Innovation*, **12** (3), 355-368.

Johnson, D. W. and Johnson, R. T. (1994) Structuring academic controversy. In: Sharan, S. (ed.) *Handbook of cooperative learning methods*. (Westport, CT: Greenwood Press).

Johnson, D. W. and Johnson, R. T. (2009) An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher* **38** (5), 365–379.

Kadefors, A. (2004) Trust in project relationships – inside the black box. *International Journal of Project Management*, **22** (3), 175-182.

Klaassen, R.G. (2018) Interdisciplinary education: a case study. *European Journal of Engineering Education*, **43** (6), 842-859. doi.org/10.1080/03043797.2018.1442417

Laal, M. and Ghodsi, S.M. (2012) 'Benefits of collaborative learning', *Procedia - Social and Behavioral Sciences*, 31, 486-490. doi.org/10.1016/j.sbspro.2011.12.091

Lee, J.H., Zhou, Y. and Ashuri, B. (2020) Key Challenges to Design Professional Liability in the Design-Build Environment. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, **12** (3). doi.org/10.1061/(ASCE)LA.1943-4170.0000413

Leite F (2016). Project-based learning in a building information modeling for construction management course, ITcon, **21**, Special issue 9th AiC BIM Academic Symposium & Job Task Analysis Review Conference, 164-176. https://www.itcon.org/2016/11

Li, M. and Campbell, J. (2008) Asian students' perceptions of group work and group assignments in a New Zealand tertiary institution. *Intercultural Education*, **19** (3), 203-216.

Lloyd-Walker, B.M., Mills, A.J. and Walker, D.H.T. (2014) Enabling construction innovation: the role of a no-blame culture as a collaboration behavioural driver in project alliances. *Construction Management and Economics*, **32** (3), 229-245.

London, K. and Pablo, Z. (2017) An actor-network theory approach to developing an expanded conceptualization of collaboration in industrialized building housing construction. *Construction Management and Economics*, **35** (8-9), 553-577.

MacDonald, J. and Mills, J. (2013) An IPD approach to construction education. *Australasian Journal of Construction Economics and Building*, **13** (2), 93-103.

MacLaren, A.J., Wilson, M., Simmonds, R., Hamilton-Pryde, A., McCarthy, J. and Milligan, A. (2017) Educating Students for the Collaborative Workplace: Facilitating Interdisciplinary Learning in Construction Courses. *International Journal of Construction Education and Research*, **13** (3), 180-202. doi.org/10.1080/15578771.2016.1267667

Manthe, M. and Smallwood, J. (2007) The appropriateness of built environment tertiary education: Perspectives of academics and postgraduate students. *Journal of Engineering, Design and Technology*, **5** (2), 102-119. doi.org/10.1108/17260530710833167

Mattessich, P.W. and Monsey, B.R. (1992) *Collaboration: What Makes It Work. A Review of Research Literature on Factors Influencing Successful Collaboration. Report for Wilder Foundation*. (St. Paul, Minnesota: Amherst H. Wilder Foundation).

Menken, S. and Keestra, M. (eds) (2016) *An Introduction to Interdisciplinary Research*. (Amsterdam: Amsterdam University Press).

Mollaoglu, S., Sparkling, A. and Thomas, S. (2015) An inquiry to move an underutilized best practice forward: barriers to partnering in the architecture, engineering and construction industry. *Project Management Journal*, **46** (1), 69-83.

Monson, C., Dossick, C.S. and Neff, G. (2015) Themes in recent research on AEC collaboration. *Working Paper Proceedings – Engineering Project Organization Conference*, University of Edinburgh, Scotland, UK. June 24-26.

Morrell, P. (2015) *Collaboration for Change: The Edge Commission Report on the Future of Professionalism.* (London: The Edge Commission). www.edgedebate.com/?page_id=2829

Nystrom, J. (2005) The definition of partnering as a Wittgenstein family-resemblance concept. *Construction Management and Economics*, **23** (5), 473-481.

Neuman, M. (2016) Teaching collaborative and interdisciplinary service-based urban design and planning studios. *Journal of Urban Design*, **21** (5), 596–615. doi.org/10.1080/13574809.2015.1100962

Okhuysen, G.A. and Bechky, B.A. (2009) Coordination in organizations. *Academy of Management Annals*, **3** (1), 463-502.

Oliver, B. (2013) Graduate attributes as a focus for institution-wide curriculum renewal: innovations and challenges. *Higher Education Research & Development*, **32** (3), 450–463. doi.org/10.1080/07294360.2012.682052

Pero, M., Moretto, A., Bottani, E. and Bigliardi, B. (2017) Environmental collaboration for sustainability in the construction industry: An exploratory study in Italy. *Sustainability*, **9** (1), 125.

Pollard, K. C., Miers. M.E. and Gilchrist. M. (2004) Collaborative learning for collaborative working? Initial findings from a longitudinal study of health and social care students. *Health and Social Care in the Community*, **12** (4), 346–358.

Reichstein, T., Salter, A.J. and Gann, D.M. (2005) Last among equals: a comparison of innovation in construction, services and manufacturing in the UK. *Construction Management and Economics*, **23** (6), 631-644. doi/org/10.1080/01446190500126940

RIBA (2014) *RIBA procedures for validation and validation criteria for UK and international courses and examinations in architecture*, Second Revision 2 May 2014. (London: Royal Institute of British Architects).

RICS (2018) *RICS Requirements and Competencies Guide*. (London: The Royal Institution of Chartered Surveyors).

Savery, J.R. (2006) Overview of problem-based learning: definitions and distinctions. *Interdisciplinary Journal of Problem-based Learning*, **1** (1), 9–20.

Savin-Baden, M., and Major, C. H. (2004) *Foundations of problem-based learning*. (Buckingham, UK: Society for Research in Higher Education and Open University Press).

Schöttle, A., Haghsheno, S. and Gehbauer, F. (2014) Defining cooperation and collaboration in the context of lean construction. *Conference Proceedings IGLC-22,* June , Oslo, 1269-1280.

Sennett, R. 2013. *Together: the Rituals, Pleasures & Politics of Cooperation*. (London: Penguin Books).

Selman, T., & Westcott, T. (2005) Interprofessional issues in construction education. In: *Construction Research Congress 2005,* April 5-7, San Diego. American Society of Civil Engineers. ascelibrary.org/doi/abs/10.1061/40754%28183%2944

Smits, P.B.A., Verbeek, J.H.A.M. and de Buisonjé, C.D. (2002) Problem based learning in continuing medical education: a review of controlled evaluation studies. *British Medical Journal*, **324**, 153–155.

Smyth, H. and Pryke, S. (2008) *Collaborative relationships in construction: developing frameworks and networks*. (West Sussex: John Wiley and Sons).

Sunding, L. and Ekholm, A. (2015) Applying social sciences to inspire behavioural change in the construction sector: an experimental study. *Construction Management and Economics*, **33** (9), 695-710.

Springer, L., Stanne, M. E., and Donovan, S. S. (1999) Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research*, **69** (1), 21–51.

Suprapto, M., Bakker, H.L.M., Mooi, H. and Hertogh, M.J.C.M. (2016) How do contract types and incentives matter to project performance? *International Journal of Project Management*, **34** (6), 1071-1087.

Susskind, R., and Susskind, D. (2015) *The future of the professions: How technology will transform the work of human experts*. (New York: Oxford University Press).

Tews, T., Skulmoski, G., Langston, C., and Patching, A. (2020) Innovation in project management education - let's get serious! *Construction Economics and Building*, **20** (3), 124-141. doi.org/10.5130/AJCEB.v20i3.704

Valdes-Vasquez, R. and Clevenger, C.M. (2015) Piloting Collaborative Learning Activities in a Sustainable Construction Class. *International Journal of Construction Education and Research*, 11:2, 79-96, DOI: 10.1080/15578771.2014.990122

Vassigh, S., Davis, D., Behzadan, A.H., Mostafavi, A., Rashid, K., Alhaffar, H., Elias, A. and Gallardo, G. (2020) Teaching Building Sciences in Immersive Environments: A Prototype Design, Implementation, and Assessment. *International Journal of Construction Education and Research*, **16** (3), 180-196, doi/org/10.1080/15578771.2018.1525445

Wang, F. and Burton, J.K. (2010) Collaborative Learning Problems and Identity Salience: A Mixed Methods Study. *Journal of Educational Technology Development and Exchange* **3** (1), Article 1. doi/org/10.18785/jetde.0301.01

Wood, D.J. and Gray, B. (1991) Towards a comprehensive theory of collaboration. *The Journal of Applied Behavioral Science*, **27** (2), 139–162.

Xue, X., Shen, Q. and Ren, Z. (2010) Critical Review of Collaborative Working in Construction Projects: Business Environment and Human Behaviors. *Journal of Management in Engineering*, **26** (4), 196-208.

Zhao, D., McCoy, A.P., Bulbul, T., Fiori, C. and Nikkhoo, P. (2015) Building Collaborative Construction Skills through BIM-integrated Learning Environment. *International Journal of Construction Education and Research*, **11** (2), 97-120. doi.org/10.1080/15578771.2014.986251