

Developing a 4-dimensional interdisciplinary learning environment for construction industry professionals

An annotated bibliography

Lead institution

The University of Queensland

Partner institutions

The University of Newcastle

University of South Australia

Project team members

Dr Chris Landorf (Team leader)

Associate Professor Graham Brewer (Team member)

Ms Kim Maund (Team member)

Mr Stephen Ward (Team member)

Professor David Williams (Team member)

Dr Trish Andrews (Curriculum designer)

Professor Stephen Loo (Project evaluator)

Dr Lorinne du Toit (Project manager)

<http://4dconstruction.architecture.uq.edu.au/>

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Introduction

This annotated bibliography derives from the literature review undertaken by Dr Chris Landorf and other project members in support of the development of a 4-dimensional (4D) construction learning environment and associated learning activities as well as the research element of the project (OLT ID13-2319).

The 4D Construction Learning Environment is intended to provide a real-life context for authentic work-integrated learning opportunities, delivered as learning activities, for students of construction-related disciplines, mainly using a problem-based learning approach.

The literature referenced here focuses on these issues and includes theoretical discussion as well as research reports from education design experiments, evaluations and other empirical studies. The bibliography highlights work, largely published since 2010, that reports, investigates or discusses the use of digital learning environments as an alternative to site visits for learners undertaking studies in construction-related professions (architecture, engineering, surveying, and construction management).

Bibliography structure

The literature has been organised into the following thematic categories:

- Work-integrated learning
- Graduate attributes in construction industry context
- Authentic learning environments
- Problem-based learning
- Teamwork and collaborative learning
- Digital learning environments
- Visualisation applications in construction disciplines
- Evaluating innovative learning technology.

Under each category, the references are listed alphabetically by first author and indicate the type of work, for example, journal article, book section, book, report, conference paper, and other online resources.

The abstracts provided have been taken directly from the source. Additional notes have been included for some works to highlight particular content.

Annotated bibliography by theme

Work-integrated learning

Title: *Realising the educational worth of integrated work experiences in higher education*

Author: Billett 2009

Journal article

Published abstract:

Across advanced industrial economies, programs in higher education are increasingly becoming occupationally specific and universities are being seen as providers of 'higher vocational education'. With this have come expectations that graduates from these programs will enjoy smooth transitions into professional practice. Aligned with these expectations is an educational emphasis on providing students with access to and engagement in authentic instances of practice, and an expectation that these will be effectively integrated within higher education programs. Consequently, it is important to understand how these kinds of educational purposes and processes can be realised, and how higher education students' experiences in both university and practice settings should be best organised and integrated to realise these purposes. This article discusses the worth of these educational purposes and bases for realising the effective integration of these work experiences. This discussion includes considerations of the kinds of curriculum and pedagogic practices needed to be enacted to secure this educational worth.

Title: *Work-based learning at higher education level: value, practice and critique*

Author: Lester and Costley 2010

Journal article

Published abstract:

Since the 1980s there has been significant growth in the engagement of higher education with workforce development, with among other things the emergence of a distinct if varied area of provision commonly referred to as work-based learning. Recent examination of practice and literature indicates a growing sophistication in the way that work-based learning is being theorised and facilitated in higher education, with its gradual emergence as a distinct field of practice and study supported by relevant pedagogies and concepts of curriculum. Tensions continue to exist between the demands and opportunities provided by the workplace and the need to develop capable practice, support personal development and maintain academic validity; however, universities are beginning to engage with these issues at a deeper level than that suggested by simple notions of employer engagement and skills development, and the evidence indicates that well-designed work-based programmes are both effective and robust.

Title: *Contextualising and integrating into the curriculum the learning and teaching of work-ready professional graduate attributes*

Author: Litchfield, Frawley, and Nettleton 2010

Journal article

Published abstract:

Government, employers and professional societies want university graduates who are better prepared for employment. The UTS [University of Technology Sydney] Work-Ready Project is a curriculum renewal initiative that aims to improve graduates' professional attributes and employability skills. The paper provides an overview of the project's curriculum renewal strategy of 'contextualised by the profession and integrated into the curriculum'. Representatives of professional societies were interviewed for their understandings of the professional attributes required of a contemporary graduate. Eleven key work-ready graduate attributes were identified, with relevant sub-attributes, understandings and skills. These formed a matrix for the development of potential learning activities. The project website gives access to matrices of generic and professionally contextualised work-ready learning activities. Each work-ready activity includes learning and teaching support resources that can be downloaded to enable easy integration into existing subjects. Formative evaluation of the project's website is presented, together with the strategies for integrating and embedding improved work-ready learning into UTS's diverse professional and disciplinary curriculum.

Notes:

This paper reports on the UTS Work-Ready Project undertaken by the authors with UTS funding. The project is a collaborative curriculum renewal initiative aimed at improving professional graduate attributes by designing work-ready learning activities that can be incorporated into existing subjects in the curriculum. The project developed a Work-Ready wiki, accessible by UTS academics, containing generic learning activities and associated teaching resources that can be/have been contextualised for each profession. Participating faculties and subject areas include Engineering and IT; Business (Accounting, Marketing); Law; Nursing, Midwifery and Health; and Science.

The key attributes were derived from interviews with representatives of professional societies. Common work-ready attributes desired by societies taking part include:

- ethics and professionalism
- a global perspective
- communications capacity
- ability to work well in a team
- ability to apply knowledge
- creative problem solving and critical thinking.

A one-page template was created for use in developing descriptions of each work-ready learning activity and the relation to desired attributes and existing curriculum. The example shown (Fig 4) is Teamwork: Group problem solving.

Title: *Good practice report: work-integrated learning*

Author: Orrell 2011

Report

Published abstract:

The Australian Learning and Teaching Council (ALTC) commissioned this report to identify good practices in work-integrated learning (WIL) in Australia through a systematic review of 28 funded studies' final reports, including WIL and discipline scoping studies, fellowships and projects.

Notes:

WIL is delineated in this report as the intentional integration of theory and practice knowledge, and a WIL program provides the means to enable this integration and may, or may not, include a placement in a workplace, or a community or civic arena.

The report is useful for WIL definition and contrast with both WIL programs and 'work-based learning'. It provides background to the current interest in and drivers for WIL uptake in higher education.

Graduate attributes in construction industry context

Title: *Loosening the Gordian knot: the role of emotional intelligence in construction*

Author: Love, Edwards, and Wood 2011

Journal article

Published abstract:

Purpose

– A perennial problem faced by construction professionals, educators and researchers is what needs to be done to improve project performance? In addressing this question, the need for the switching of lenses from the dominant operations paradigm to one that focuses on organizational behavior is advocated. Emotional intelligence (EI) is a growing area of behavioral investigation which is considered to be positively related to occupational success, satisfaction, emotional health and adjustment. This paper aims to look at its influence.

Design/methodology/approach

– In this paper emotions are examined and the usefulness measures of EI are discussed and critiqued. The paper then looks more closely at the way in which EI may relate to success in a common position within the construction industry, that of the construction manager.

Findings

– Recommendations are made on the ways in which research and practice can contribute to project success through attention to the link between EI and project performance.

Practical implications

– In construction, there is a real need to examine how individuals, teams and the structure of projects influence behavior, if the improvements being sought within the industry are to be realistically achieved. Potentially EI, in conjunction with other assessment tools, could be used by construction organizations to significantly improve the performance of construction managers and their teams.

Originality/value

– Several researchers in construction have begun to examine EI but have limited understanding about its underlying origins and the problems associated with many of the tools that have been developed. The paper provides invaluable guidance about how EI could be used to improve the performance of construction projects.

Title: *Design error reduction: toward the effective utilization of building information modeling*

Author: Love et al. 2011

Journal article

Published abstract:

An advocated panacea for reducing design errors and rework in construction and engineering projects is building information modeling (BIM). Yet, it would appear that advocates of BIM have overlooked why and how design errors occur. In this article, the nature of error is explained and the principal underlying causes identified with reference to the normative literature and the authors phenomenological research. A systemic model for reducing design errors is presented and the enabling role of BIM discussed.

Title: *Building and construction: learning and teaching academic standards statement*

Author: Newton 2011

Report

Extract (p. 9):

Upon completion of a bachelor degree in building and construction, graduates will be able to:

- integrate and evaluate the fundamental principles and technical knowledge of building and construction technology, management, economics and law
- identify and resolve typical building challenges with limited guidance, employing appropriate evidence-based problem-solving and decision-making methodologies
- critically and creatively reflect on personal behaviours and capabilities in the context of entry to professional practice
- interpret and negotiate building and construction information, instructions and ideas with various project stakeholders
- research and develop methods and strategies for the procurement and delivery of contemporary construction work
- demonstrate an integrated understanding of both the theory and practice of building and construction based on experience.

Title: *Understanding architectural education in Australasia*

Author: Ostwald and Williams 2008

Report

Published abstract:

The present document provides a detailed overview of who we – the members of the architecture discipline in academia – are, how we came to the current situation and what our prevailing concerns are. While the document provides an overview of architectural academia, its ultimate focus is on teaching and learning; on the pedagogical challenges we face, and the scholarly and instructional opportunities available to us. Importantly, the document does not offer solutions to these challenges or responses to the opportunities. Future, more detailed work must be undertaken on many of these areas before they can usefully benefit the discipline. Instead, the document supplements the detailed overview of architecture schools with an analysis of the teaching and learning priorities of the discipline. It offers advice on how these issues could be usefully approached and how individual schools might adopt them.

Title: *Learning and teaching academic standards statement for architecture*

Author: Savage 2011

Report

Published abstract:

The development of the Learning and Teaching Academic Standards Statement for Architecture (the Statement) centred on requirements for the Master of Architecture and

proceeded alongside similar developments in the building and construction discipline under the guidance and support of the Australian Deans of Built Environment and Design (ADBED). Through their representation of Australian architecture programs, ADBED have provided high-level leadership for the Learning and Teaching Academic Standards Project in Architecture (LTAS Architecture).

Title: *Information management in UK-based architecture and engineering organizations: drivers, constraining factors, and barriers*

Author: Sheriff et al. 2011

Journal article

Published abstract:

The need to improve collaborative working, knowledge sharing, and operational effectiveness has made effective Information Management a growing priority for Architecture and Engineering (A & E) organizations in the UK construction industry. While significant research has been carried out in the construction industry on project Information Management, limited work has been carried out to understand Information Management from an organisational paradigm. This paper presents the findings of an investigation into the nature of Information Management within A & E organizations in the UK construction industry. Interviews were conducted with experts across nine large architectural and multidisciplinary consultancies, the outputs of which were analysed using thematic analysis. From this, 26 themes across three core categories classed as drivers, constraining factors, and barriers which shape Information Management practices in construction organizations emerged. The findings show that Information Management is indeed of strategic significance to organizations and an organizational dimension is necessary to better align information needs with an organisation's operational processes. They also show that context-dependent factors exist which shape the nature of Information Management in line with the specific needs of each organizations. Therefore, the effectiveness of an organisation's Information Management practices is not absolute, but rather relative to its level of alignment to the organisation's chosen mode of operation. The findings provide a much needed practical view of the complexities of Information Management, highlighting that particularly within multidisciplinary organizations; a unifying approach is much more practical and appropriate than a single approach to managing information.

Authentic learning environments

Title: *Authentic e-learning in higher education*

Author: Herrington 2009

Conference paper

Published abstract:

Technologies can be used as powerful cognitive tools when they are used, not for information delivery, but as instruments used by students to solve complex problems. A common way to use technology in universities is to use it to deliver information or teach concepts and skills (learning from technology). Another is to teach particular technologies and their uses (learning about technology). Perhaps the most powerful use of technology in higher education is where technologies are used as tools (learning with technology) in authentic learning environments. This paper argues that e-learning technologies afford the design and creation of truly innovative authentic learning tasks. The theoretical foundations of this approach are strong, and they are explored. A range of strategies are described that draw on principles of authentic learning, and they are illustrated with examples and activities from higher education e-learning contexts. Finally, the paper proposes that a more comprehensive approach to investigating the effectiveness of authentic learning designs can be accomplished through design research.

Notes:

Authentic learning in this paper is understood as ‘the notion of learning knowledge and skills in contexts that reflect the way the knowledge will be useful in real life’ (Collins 1988, 2). The task that is set for students is the most important component. The author identifies ten criteria that distinguish, and can be used to guide, the design and development of authentic tasks:

- real-world relevance
- ill-defined
- complex
- provide the opportunity for students to examine the task from different perspectives, using a variety of resources
- opportunity for collaboration
- opportunity for reflection
- can be integrated and applied across different subject areas and lead beyond domain-specific outcomes
- are seamlessly integrated with assessment
- create polished products valuable in their own right
- allow competing solutions and diversity of outcome.

A wide variety of current and emerging technologies, particularly participatory tools, can be incorporated into authentic learning tasks as cognitive tools as well as being used both in the processes and products of the e-learning environment. However, it is not yet entirely clear how best to do this. The paper investigating the effectiveness of authentic learning designs through design research.

Title: *Authentic learning environments*

Author: Herrington, Reeves, and Oliver 2014

Book chapter

Published abstract:

Authentic learning is a pedagogical approach that situates learning tasks in the context of future use. Over the last two decades, authentic learning designs have captured the imaginations of innovative educators who see the approach as a means to enable students to develop robust knowledge that transfers to real-world practice. Authentic learning has its foundations in the theory of situated cognition, together with other pedagogical approaches developed over the last two decades, such as anchored instruction. It offers an alternative instructional model based upon sound principles for the design and implementation of complex and realistic learning tasks ... This chapter reviews the seminal and recent literature in the field and provides a model of authentic learning for the design of learning environments across educational sectors.

Problem-based learning

Title: *The problem of projects: understanding the theoretical underpinnings of project-led PBL*

Author: Hanney and Savin-Baden 2013

Journal article

Published abstract:

For many years there has been a sharp division between project-based learning, and problem-based learning, with the former adopting a more technical rationalist approach while the latter adopts a more Socratic or dialogic approach. This article argues that current notions of project-based learning are too narrow and that combining the two approaches will improve student engagement and criticality. This article begins by outlining the key differences between project-based, and problem-based learning, suggesting a new constellation. It then provides an exemplar in the form of a case study that sought to undertake such a combination, and reports on implications for practice.

Title: *Theory to reality: a few issues in implementing problem-based learning*

Author: Hung 2011

Journal article

Published abstract:

The success of an intervention depends not only upon its theoretical soundness, but also on proper implementation that reflects the guidelines derived from its theoretical conception.

Debates surrounding the effectiveness of problem-based learning (PBL) have focused on its theoretical conception and students' learning outcomes, but implementation is seemingly absent from the picture. This paper attempts to describe what research evidence is needed to fill in this missing information and provide a clearer picture of PBL. The author examines current PBL implementation practices and identifies potentially confounding variables that may play a role in inconsistent or conflicting research results in PBL. For example, various models of PBL have been developed and implemented to afford the specific instructional needs of the institution or learner population. These PBL models are in fact quite different in terms of the nature of problem solving and the degrees of self-directed learning, which theoretically, should result in different types of learning outcomes. Without distinguishing the models used, the results of comparative PBL research could have been confounded. Furthermore, human factors are another set of confounding variables that could influence the students' learning processes and consequently affect PBL implementations and research results. To remedy these problems and reach PBL's full potential, as well as obtain a more accurate picture of PBL as an instructional method and its effects on students' learning, some fundamental changes are needed.

Notes:

Debates surrounding the effectiveness of problem-based learning (PBL) have focused on its theoretical conception and students' learning outcomes, but implementation is seemingly absent from the picture. Hung argues that the success of an intervention depends not only upon its theoretical soundness, but also on proper implementation that reflects the guidelines derived from its theoretical conception. The author examines current PBL implementation practices and identifies potentially confounding variables that may play a role in inconsistent or conflicting research results in PBL. Among these are differences in PBL models, which are not necessarily equivalent, and various human factors especially related to group work and facilitation skills. Hung also indicates that institutional and administrative factors are likely to play a role but finds this beyond the scope of his paper.

Hung provides a concise review of the theoretical base, assumptions and promise of PBL. Among the key components (or expectations) of PBL are (1) problem-driven learning, (2) self-directed learning, and (3) collaborative learning.

Hung argues that from a comparative perspective, PBL research should report (1) the instructional needs that the PBL implementation is trying to fulfil, (2) learners' characteristics, (3) the PBL model used in their practice or studies, (4) the rationale for the PBL model selection, (5) the learning outcomes being measured, and (6) the type of assessment used. The research question should be 'Does each PBL model produce its desired effects in relation to its respective learner characteristics and instructional needs?' rather than 'Is PBL effective?' This research approach would also provide educators implementing PBL with guidelines for what model best suits particular circumstances. In particular, assessment is vital to both PBL research and implementation outcomes. Performance-based, formative, multiple-source oriented formats have gradually become the mainstream assessment formats in PBL but researchers should still report on reliability and validity of each instrument.

Concluding, Hung points to various recent recommendations for improving PBL outcomes through instructional intervention. Among these:

- explicitly teaching PBL philosophy (why) and process (how)
- providing appropriate scaffolding
- motivating students to be responsible active learners
- using a solid design model (such as 3C3R: content, context, connection, researching, reasoning, and reflecting) to guide PBL problem construction (from Hung 2006. 'The 3C3R Model: A Conceptual Framework for Designing Problems in PBL'. *Interdisciplinary Journal of Problem-Based Learning* 1 (1): 55–77).

Title: *Teaching critical management skills: the role of problem-based learning*

Author: Joham and Clarke 2011

Journal article

Published abstract:

This paper explores problem-based learning (PBL) as a vehicle for developing critical management skills and preparing students for their future careers. Using student reflections and facilitator observations the paper presents the nature of individuals' experiences with learning and teaching in a PBL setting in the management discipline. The study investigates: (1) how students engage in and experience the learning process in a PBL context, particularly in relation to the development of group processes; and (2) the skills developed through both learning and assessments in a PBL course. The paper concludes that, for management educators, successful PBL requires adequate structure and support to ensure that students move through the PBL cycle identified by Hmelo-Silver.

Title: *All problems are not equal: implications for problem-based learning*

Author: Jonassen and Hung 2008

Journal article

Published abstract:

Problem-based learning (PBL) is an instructional model that assumes the centrality of problems to learning. Research on PBL has focused on student learning, student roles, tutor roles, problem design, and technology use (Hung, Jonassen, & Liu, 2008), but little attention in the PBL literature has been paid to the nature of the problems that provide the focus for PBL. In this paper, we articulate a model for evaluating problem difficulty. Problem difficulty is defined in terms of complexity, including breadth of knowledge, attainment level, intricacy of procedures, relational complexity, and problem structuredness including intransparency, heterogeneity of interpretations, interdisciplinarity, dynamicity, or competing alternatives. Based on these characteristics, we identify four classes of problems and then describe three different kinds of problems: decision-making, diagnosis-solution, and policy problems. We then examine the amenability of these classes and problem types as foci for PBL curricula. Finally, we challenge PBL researchers and designers to consider the issue of problem difficulty in articulating PBL curricula.

Notes:

The authors ask whether problem-based learning (PBL) methods are applicable to different problem types. PBL is frequently used in medical training and the most common problem type is 'diagnosis-solution'. However, other disciplines (for example, architecture, engineering) focus more on 'design problems' while others (for example, business management, public administration) utilise 'decision-making' and policy analysis problems.

They argue that PBL is not universally applicable – 'the primary goal of PBL is to enhance students' application of knowledge, problem solving, and self-directed learning skills by requiring them to actively articulate, understand, and solve problems. PBL is problem focused, where learners begin learning by addressing simulations of an authentic problem. The subject matter content and skills to be learned are organized around problems, rather than as a hierarchical list of topics' (p. 15). 'PBL problems should be:

- open ended, ill structured, however,
 - with a moderate degree of structuredness
- complex, however, the degree of complexity should
 - be challenging and motivating, engaging students' interests
 - provide opportunities for students to examine the problem from multiple perspectives or disciplines
 - be adapted to students' prior knowledge
 - be adapted to students' cognitive development and readiness
- authentic
 - contextualized as to students' future or potential workplaces' (p. 16).

Title: *The power of problem-based learning in developing critical thinking skills: preparing students for tomorrow's digital futures in today's classrooms*

Author: Kek and Huijser 2011

Journal article

Published abstract:

This article describes problem-based learning as a powerful pedagogical approach and an aligned teaching and learning system to explicitly and directly teach critical thinking skills in a broad range of disciplines. Problem-based learning is argued to be a powerful pedagogical approach as it explicitly and actively engages students in a learning and teaching system, characterised by reiterative and reflective cycles of learning domain-specific knowledge and doing the thinking themselves. At the same time, students are guided and coached by the problem-based learning teacher, who models critical thinking skills in the acquisition of the domain-specific knowledge. This article will explore what critical thinking actually means. What are critical thinking skills? How best to teach such skills? What is the potential role of problem-based learning in teaching critical thinking skills? Finally, the article reflects on how

critical thinking can be developed through problem-based learning as a pedagogical approach in an aligned learning and teaching context.

Title: *Problem-based learning: a critical rationalist perspective*

Author: Parton and Bailey 2008

Journal article

Published abstract:

Although problem-based learning is being adopted by many institutions around the world as an effective model of learning in higher education, there is a surprising lack of critique in the problem-based learning literature in relation to its philosophical characteristics. This paper explores epistemology as a starting point for investigating the theoretical underpinnings of problem-based learning as a learning model. Criticisms of empiricism are analysed in terms of the perceived learning outcomes of learners undertaking a problem-based learning curriculum. It is argued that models of empiricism theorised by philosophers such as Bacon, Locke and Hume cannot fully account for the learning model found in problem-based learning curricula. It is proposed that an alternative epistemological approach is needed. The work of Karl Popper is discussed, whose critical rationalist epistemology emphasises the generation of bold conjectures and criticism. Popper's work shows a positive contribution to the demands of higher education, characterised by learners who are serious about making professional progress. The paper concludes by critically analysing the tensions and contradictions of problem-based learning in light of Popper's epistemological theory of critical rationalism. It is argued that a critical rationalist perspective has educational benefits for students as it creates an environment rich in critical thinking, reading and writing and values disjunction and challenge.

Teamwork and collaborative learning

Title: *Team effectiveness and team development in CSCL*

Author: Fransen, Weinberger, and Kirschner 2013

Journal article

Published abstract:

There is a wealth of research on computer-supported cooperative work (CSCW) that is neglected in computer-supported collaborative learning (CSCL) research. CSCW research is concerned with contextual factors, however, that may strongly influence collaborative learning processes as well, such as task characteristics, team formation, team members' abilities and characteristics, and role assignment within a team. Building on a critical analysis of the degree to which research on CSCW translates to CSCL, this article discusses the mediating variables of teamwork processes and the dynamics of learning-teams. Based on work-team effectiveness models, it presents a framework with key variables mediating

learning-team effectiveness in either face-to-face or online settings within the perspective of learning-team development

Title: *Collaboration down under: investigating team learning in Australia in architecture and related design contexts*

Author: Tucker 2012

Conference paper

Published abstract:

This position paper reports on an Australian Learning Teaching Council (ALTC) funded project – “Enhancing and Assessing Group and Team Learning in Architecture and Related Design Contexts.” This is a two-year project, commencing in November 2011, which is investigating best practice in Australian higher education for the teaching of teamwork in the design disciplines, with a focus on Architecture. At the time of the conference presentation, data on current practices will be reported on that has been collected and analysed from four universities in Australia. The project aims to: highlight and develop innovative approaches to collaborative studio-based learning; structure team learning within curricula; develop graduate attributes for teamwork; and inform assessment of team design that supports team-working skills and increased learner confidence.

Title: *The architecture of teamwork: examining relationships between teaching, assessment, student learning and satisfaction with creative design outcomes*

Author: Tucker and Abbasi 2014

Journal article

Published abstract:

Student satisfaction with teamwork experiences is important for two interrelated reasons. First, students learn about teamwork more effectively when they view their teamwork learning experience more positively. Second, their satisfaction with prior teamwork learning has an impact on future teamwork learning – because team effectiveness is influenced by attitudes and motivations to teamwork shaped by past experience. This paper draws on data collected from almost 196 students at 4 Australian universities. It considers the relationships between architecture students’ satisfaction with two dimensions of teamwork – its processes and its outcomes – and five pedagogic factors that teachers can control: team size, assessment, team formation, the teaching of teamwork skills and knowledge, and feedback on teamwork skills and processes. The results indicated that a student’s perception of whether assessment was fair was the greatest predictor of satisfaction. Through an understanding of the factors that contribute to positive learning experiences for students in teams, suggestions are given on how design educators might better support student learning in teamwork assignments and student learning of how to design in teams.

Digital learning environments

Title: *What are the learning affordances of 3-D virtual environments?*

Author: Dalgarno and Lee 2010

Journal article

Published abstract:

This article explores the potential learning benefits of three-dimensional (3-D) virtual learning environments (VLEs). Drawing on published research spanning two decades, it identifies a set of unique characteristics of 3-D VLEs, which includes aspects of their representational fidelity and aspects of the learner–computer interactivity they facilitate. A review of applications of 3-D VLEs is presented, leading to the identification of a series of learning affordances of such environments. These affordances include the facilitation of tasks that lead to enhanced spatial knowledge representation, greater opportunities for experiential learning, increased motivation/engagement, improved contextualisation of learning and richer/more effective collaborative learning as compared to tasks made possible by 2-D alternatives. The authors contend that the continued development of and investment in 3-D games, simulations and virtual worlds for educational purposes should be considered contingent on further investigation into the precise relationships between the unique characteristics of 3-D VLEs and their potential learning benefits. To this end, they conclude by proposing an agenda or ‘roadmap’ for future research that encompasses empirical studies aimed at exploring these relationships, as well as those aimed at deriving principles and guidelines to inform the design, development and use of 3-D virtual environments for learning.

Notes:

The authors indicate (p. 11) that ‘A 3D VE can be defined as an environment that “capitalizes upon natural aspects of human perception by extending visual information in three spatial dimensions”, “may supplement this information with other stimuli and temporal changes” and “enables the user to interact with the displayed data” (Wann & Mon-Williams, 1996, p. 833)’. Three-dimensionality, smooth temporal changes and interactivity are the most important features that distinguish 3D VLEs from other types of VLEs, such as those provided by a learning management system (for example, Blackboard or Moodle). This paper focuses on VR (virtual reality) applications running on a standard personal computer. This is referred to as a ‘desktop virtual environment’ to differentiate it from an ‘immersive virtual environment’, which needs specialised hardware, such as head-mounted displays and multi-wall Cave Automatic VE systems.

Usefully, the authors also review the usage of ‘affordance’ as a concept on p. 17 – ‘The term “affordance” was first coined by Gibson (1979), who used it to refer to the functional properties that determine the possible utility of an object or environment (cited in Salomon, 1993). According to Greeno (1994), “an affordance relates attributes of something in the environment to an interactive activity by an agent who has some ability” (p. 338). A number of authors have also used “affordance” in educational contexts to describe the relationships between the properties of an educational intervention and the characteristics of the learner

that enable certain kinds of learning to occur (Kirschner, 2002), while others stress the importance of analysing how the affordances of information and communication technologies (ICTs) can be used to facilitate particular approaches to teaching and learning (see for example, Conole & Dyke, 2004). Bower (2008) proposes a methodology for matching the affordance requirements of learning tasks with the technological affordances of ICT tools, which can be used to help guide and inform the processes of technology selection and learning design. [The authors] concur with Bower's implicit conception of affordances while also acknowledging that the technologies themselves do not directly cause learning to occur but can afford certain learning tasks that themselves *may* result in learning or give rise to certain learning benefits.'

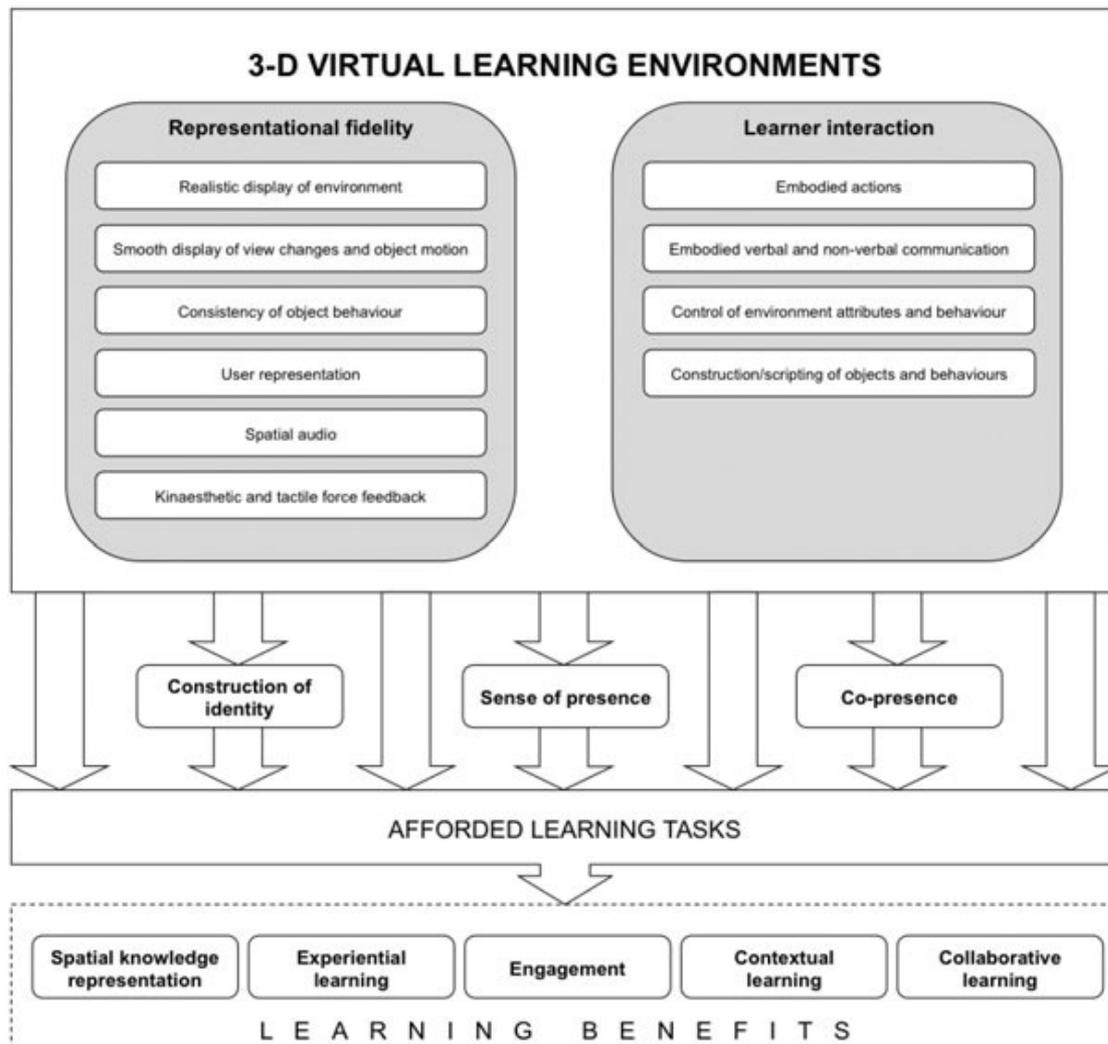


Figure 2 (p. 24) summarises the affordances that this sort of technology can enable but note that the VR applications discussed largely rely on graphics and games engines to provide fidelity and interactivity (that is, not the same technology as the AEB 4D application).

Title: *Development, Deployment and Educational Assessment of Advanced Immersive Learning Environments for Process Engineering*

Author: Cameron et al. 2009

Report

Extract – Executive summary (p. 4):

“Bring the plant to the student, if you can’t get the student to the plant”!

The outcomes of this project on immersive VR systems in process engineering have accomplished the above learning possibility. A collaborative team has developed two prototype environments that have broken new ground in engaging instructors, students, industrial operators and trainers with a range of process engineering concepts and practices.

Built on an early prototype first developed at the University of Queensland, a partnership between 5 Australian Chemical Engineering departments and two industrial collaborators has successfully developed two immersive environments. These environments allow instructors to demonstrate the industrial outworking of complex engineering principles and at the same time provide an information-rich environment for development of numerous learning activities for students. These activities are built inside the 3D environment as well as being developed by instructors with reference to the environment. This architecture provides a unique resource for a wide range of learning challenges from the earliest years of an engineering program to the capstone design activities. It also has important applications within industry and secondary education to inform, enthuse and deepen understanding of these complex engineering operations.

Title: *The use of ‘exploratory learning’ for supporting immersive learning in virtual environments*

Author: de Freitas and Neumann 2009

Journal article

Published abstract:

User interfaces are becoming more intuitive following the requirements of the individual learner and reinforcing the drive towards more personalised learning and greater learner autonomy. There are clearly a new set of challenges emerging for teaching practitioners that will have implications upon not just what is learned but importantly upon lesson planning. This paper explores these changes to teaching through a consideration of an exploratory learning model which allows practitioners to rethink how they teach in 3D and immersive spaces where learning sequences and experiences are choreographed to support peer interactions and exchanges. The ELM extends from Kolb’s experiential learning model to adapt the use of 3D applications, and provides examples from research and development projects to exemplify how the model works in practice. Teaching in these contexts provides less emphasis upon curriculum and more emphasis upon sequencing learning experiences, meta-reflection, peer assessment and group work.

Title: *Virtual learning environments*

Author: Dillenbourg, Schneider, and Synteta 2002

Conference paper

Published abstract:

Is the concept of 'virtual learning environment' just a popular label to describe any educational software? No, the concept includes several interesting features that justify the use of a specific label. We review these features in the first part of our contribution. Do these features guarantee pedagogical effects? No, we review in the second some potential contributions of virtual learning environments. Turning potential effects into [sic] actual outcomes is the challenge of designers.

Notes:

Authors argue that virtual learning environments can be identified by the following features:

- A virtual learning environment is a designed information space.
- A virtual learning environment is a social space: educational interactions occur in the environment, turning spaces into places.
- The virtual space is explicitly represented: the representation of this information/social space can vary from text to 3D immersive worlds.
- Students are not only active, but also actors: they co-construct the virtual space
- Virtual learning environments are not restricted to distance education: they also enrich classroom activities.
- Virtual learning environments integrate heterogeneous technologies and multiple pedagogical approaches.
- Most virtual environments overlap with physical environments.

Title: *Engaging with blended learning to improve students' learning outcomes*

Author: Francis and Shannon 2013

Journal article

Published abstract:

When blended learning is embraced to enhance learning in engineering (architectural), design and architecture, we argue it is a best-practice instructional mode. Blended learning is the seamless amalgamation of carefully selected online modules with face-to-face instruction. This paper evaluates case studies of the introduction of blended learning in these disciplines. It demonstrates that students who do not engage with blended learning are academically disadvantaged. Alignment of the blended mode of delivery and the mode of assessment is next considered. Two case studies of the introduction of blended modes of assessment, for improved student satisfaction with feedback, are evaluated. Finally, the reliance upon non-faculty to provide both blended learning and assessment is evaluated using qualitative research methods to establish the barriers to adoption of what is now considered best educational practice.

Title: *Extended immersive learning environment: a hybrid remote/virtual laboratory*

Author: Marcelino et al. 2010

Journal article

Published abstract:

This paper presents a collaborative virtual learning environment, which includes technologies such as 3D virtual representations, learning and content management systems, remote experiments, and collaborative learning spaces, among others. It intends to facilitate the construction, management and sharing of knowledge among teachers and students, in a global perspective. The environment proposes the use of 3D social representations for accessing learning materials in a dynamic and interactive form, which is regarded to be closer to the physical reality experienced by teachers and students in a learning context. A first implementation of the proposed extended immersive learning environment, in the area of solid mechanics, is also described, including the access to theoretical contents and a remote experiment to determine the elastic modulus of a given object.

Title: *Interaction design and usability of learning spaces in 3D multi-user virtual worlds*

Author: Minocha and Reeves 2010

Book chapter

Published abstract:

Three-dimensional virtual worlds are multimedia, simulated environments, often managed over the Web, which users can 'inhabit' and interact via their own graphical, self-representations known as 'avatars'. 3D virtual worlds are being used in many applications: education/training, gaming, social networking, marketing and commerce. Second Life is the most widely used 3D virtual world in education. However, problems associated with usability, navigation and wayfinding in 3D virtual worlds may impact on student learning and engagement. Based on empirical investigations of learning spaces in Second Life, this paper presents design guidelines to improve the usability and ease of navigation in 3D spaces. Methods of data collection include semi-structured interviews with Second Life students, educators and designers. The findings have revealed that design principles from the fields of urban planning, Human-Computer Interaction, Web usability, geography and psychology can influence the design of spaces in 3D multi-user virtual environments.

Title: *Architectures for developing multiuser, immersive learning scenarios*

Author: Nadolski et al. 2012

Journal article

Published abstract:

Multiuser immersive learning scenarios hold strong potential for lifelong learning as they can support the acquisition of higher order skills in an effective, efficient, and attractive way. Existing virtual worlds, game development platforms, and game engines only partly cater for the proliferation of such learning scenarios as they are often inadequately tuned for learning. First, this study aims to identify architectures that more effectively support the development of multiuser immersive learning scenarios. Second, this study takes up the challenge to define and assemble more flexible architectures that cater for fast and easy development, which will become important in the current period of economic breakdown. Third, this study describes how such architectures should enable research into guidelines for multiuser immersive learning scenario design and development. This study outlines a method for defining and setting up such architectures by using experts and existing literature.

Visualisation applications in construction disciplines

Title: A collaborative augmented reality based modeling environment for construction engineering and management education

Author: Behzadan, Iqbal, and Kamat 2011

Conference paper

Published abstract:

Current instruction methods of teaching construction engineering and management rely heavily on traditional pedagogical techniques such as in-class instruction and coursework in core subjects. Such methods often fail to prepare students to effectively handle the complexities of actual projects as they provide limited opportunities for hands-on experience. For example, creating an effective relationship and intuitive mapping between the real world and the abstract knowledge gained through tools such as CAD and BIM is still a challenge. This paper presents the initial results of a project aimed to transform the current learning process in construction by designing and implementing an interactive augmented reality (AR) learning tool to help students develop a comprehensive understanding of construction equipment, processes, and operational safety. A descriptive account of how this evolving technology can be used to create a transformative learning and educational environment is provided, along with a discussion of several design and implementation challenges.

Notes:

For reasons similar to those in the 4D construction learning environment project proposal, this USA paper reports on a project exploring the potential of a digital (augmented reality) learning environment as an alternative to site visits for students undertaking programs in construction industry professions.

The aim of the project is 'the design and implementation of a learning tool that uses augmented reality (AR) visualization and real time object tracking to enable students to

develop a comprehensive understanding of the equipment and processes and operational safety through real time interaction with a remote site' (p. 3575).

Augmented reality (AR) differs from virtual reality (VR). AR does not 'replace the real world, rather the real world is supplemented with relevant synthetic information, and thus real and virtual objects coexist in an augmented space (Azuma 1997)' (p. 3575). Using suitable devices, theoretical or design content can be 'overlaid' on the actual object or location being viewed by the user. In this study, the authors have linked AR devices to enable simultaneous group (multi-user) access, for example, to a remote construction site. The paper reports on the 'proof-of-concept' stage.

Title: *Student visualization: using 3-D models in undergraduate construction management education*

Author: Glick, Porter, and Smith 2012

Journal article

Published abstract:

Three-dimensional computer models used in the classroom may help increase student understanding of new and complex course material, and provide an opportunity to enhance visuo-spatial skills. Students lacking these abilities may have difficulty visualizing construction systems and components. This study explores the results of a survey conducted in the Fall of 2009 as part of a curriculum development project in the Construction Management Department at one University. Over twenty 3D models were created from figures in the course text and used, to varying degrees, in three sections of a materials and methods class. Focusing on four CSI divisions, the results indicate that students' perceptions of learning masonry ($F(2,123) = 12.01, p = 0.001$) and metals ($F(2,122) = 3.6, p = 0.031$) increased when 3D models were part of the course material presentation. The results were also used to direct resources for additional 3D model development.

Title: *Educational simulation in construction: virtual construction simulator*

Author: Nikolic, Jaruhar, and Messner 2011

Journal article

Published abstract:

Students in the architecture, engineering, and construction disciplines are often challenged with visualizing and understanding the complex spatial and temporal relationships involved in designing and constructing three-dimensional (3D) structures. An evolving body of research traces the use of educational computer simulations to enhance student learning experiences through testing real-world scenarios and the development of student decision-making skills. Ongoing research at Pennsylvania State University aims to improve engineering education in construction through interactive construction project learning applications in an immersive virtual reality environment. This paper describes the first- and

second-generation development of the Virtual Construction Simulator (VCS), a tool that enables students to simultaneously create and review construction schedules through 3D model interaction. The educational value and utility of VCS was assessed through surveys, focus group interviews, and a student exercise conducted in a construction management class. Results revealed VCS is a valuable and effective four-dimensional (4D) model creation and schedule review application that fosters collaborative work and greater student task focus. This paper concludes with a discussion of the findings and the future development steps of the VCS educational simulation.

Evaluating innovative learning technology

Title: *Assessments for learning, of learning, and as learning in 3D immersive virtual environments*

Author: Code and Zap 2013

Conference paper

Published abstract:

The key to education reform lies in exploring alternative forms of assessment. Alternative performance measures provide a more valid measure than multiple-choice tests of students' conceptual understanding and higher-level skills such as problem solving. Advances in immersive virtual environment technologies are creating new possibilities for learning and assessment. Rigorous, empirically based research studies are underway that aim to explore this potential. One such possibility is through the use of immersive 3D technologies that aim to situate students in an environment that promotes inquiry and sets the context for assessment. This paper describes three on-going research projects that are using immersive 3D virtual environments as a platform in which to enable the summative, self-, and formative assessments of student learning.

Title: *Students' perceptions of their learning experiences in an authentic instructional design context*

Author: Dabbagh and Williams Blijd 2010

Journal article

Published abstract:

The purpose of this case study was to examine students' perceptions of their learning experiences while working on a real world instructional design project in a performance oriented team in the context of a situated and problem-based learning environment. Participants were 11 graduate students enrolled in a learning-by-doing instructional design program. The results revealed that overall students had a positive perception of their learning experiences despite difficulties related to managing expectations, which led to initial feelings of anxiety and confusion. These expectations were primarily related to the nature of the project, the degree of scaffolding provided, and teamwork.

Notes:

The research focused on three questions:

1. What were students' perceptions of their learning experiences with regard to working on a real world instructional design project?
2. What were students' perceptions of their learning experiences with regard to working on a performance oriented team?
3. What were students' perceptions of their learning experiences with regard to their abilities to link theory to practice?

Design was exploratory, case based and qualitative. Data was collected via interviews and required twice-monthly personal reflections of participants, and analysed thematically.

Title: *What does 'impact' mean in the evaluation of learning technology?*

Author: Oliver and Harvey 2002

Journal article

Published abstract:

Whilst many projects in Higher Education are expected to demonstrate their impact, quite what this requirement means is often left unspecified. This paper draws on the experiences of the EFFECTS project in an attempt to illuminate this issue. The EFFECTS evaluation framework is used to structure this discussion, which explores the complexities associated with identifying impact in terms of student learning, changes in practice for academics, changes within an organisation and national development. Common themes arising from these areas are then identified. Importantly, while practical issues are considered, the purpose of this discussion is not to 'solve' this complexity – instead, its purpose is to recognise it, and to consider the implications for evaluators of working in such settings.

Title: *Evaluating the quality of work-integrated learning curricula: a comprehensive framework*

Author: Smith 2012

Journal article

Published abstract:

There are many different forms that work-integrated learning (WIL) takes and variants go by a range of different names. Based on current literature, key dimensions, shared by the various and disparate forms of WIL curricula, were identified and operationalised in a measurement model. The key dimensions identified were: authenticity, integrated learning supports (both at university and the workplace), alignment (of teaching and learning activities and assessments with integrative learning outcomes), supervisor access and induction/preparation processes. It is suggested that variations in the way that WIL courses or subjects are designed within these dimensions are the basis for different expressions of

the quality of such courses. A latent construct measurement model was developed and validated with a sample of Australian and UK students. This paper presents the model and discusses the results of the validation study. It is proposed that the measures validated in this study will be useful for evaluating a wide variety of WIL curricula.

References

- Behzadan, A.H., A. Iqbal, and V.R. Kamat. 2011. 'A Collaborative Augmented Reality Based Modeling Environment for Construction Engineering and Management Education'. *Simulation Conference (WSC), Proceedings of the 2011 Winter*, December, 3568–76. doi:10.1109/WSC.2011.6148051.
- Billett, Stephen. 2009. 'Realising the Educational Worth of Integrating Work Experiences in Higher Education'. *Studies in Higher Education* 34 (2): 827–43.
- Cameron, Ian, Caroline Crosthwaite, David Shallcross, John Kavanagh, Geoff Barton, Nicoleta Maynard, Moses Tade, and Andrew Hoadley. 2009. 'Development, Deployment and Educational Assessment of Advanced Immersive Learning Environments for Process Engineering'. Strawberry Hills, NSW: ALTC. <http://www.olt.gov.au/resource-development-deployment-educational-ug-2009>.
- Code, Jillianne, and Nick Zap. 2013. 'Assessments for Learning, of Learning, and as Learning in 3D Immersive Virtual Environments'. In *World Conference on Educational Multimedia, Hypermedia and Telecommunications 2013*, edited by Jan Herrington, Alec Couros, and Valerie Irvine, 159–66. Victoria, Canada: AACE. <http://www.editlib.org/p/111949>.
- Dabbagh, Nada, and Cecily Williams Blijd. 2010. 'Students' Perceptions of Their Learning Experiences in an Authentic Instructional Design Context'. *Interdisciplinary Journal of Problem-Based Learning* 4 (1): 6–29.
- Dalgarno, Barney, and Mark J. W. Lee. 2010. 'What Are the Learning Affordances of 3-D Virtual Environments?' *British Journal of Educational Technology* 41 (1): 10–32.
- de Freitas, Sara, and Tim Neumann. 2009. 'The Use of "Exploratory Learning" for Supporting Immersive Learning in Virtual Environments'. *Computers & Education* 52 (2): 343–52. doi:10.1016/j.compedu.2008.09.010.
- Dillenbourg, Pierre, Daniel Schneider, and Paraskevi Synteta. 2002. 'Virtual Learning Environments'. <https://telearn.archives-ouvertes.fr/hal-00190701/document>.
- Francis, Rebecca, and Susan J Shannon. 2013. 'Engaging with Blended Learning to Improve Students' Learning Outcomes'. *European Journal of Engineering Education* 38 (4): 359–69. doi:10.1080/03043797.2013.766679.
- Fransen, Jos, Armin Weinberger, and Paul A Kirschner. 2013. 'Team Effectiveness and Team Development in CSCL'. *Educational Psychologist* 48 (1): 9–24.
- Glick, Scott, Dale Porter, and Charles Smith. 2012. 'Student Visualization: Using 3-D Models in Undergraduate Construction Management Education'. *International Journal of Construction Education and Research* 8 (1): 26–46.
- Hanney, Roy, and Maggi Savin-Baden. 2013. 'The Problem of Projects: Understanding the Theoretical Underpinnings of Project-Led PBL'. *London Review of Education* 11 (1): 7–19. doi:10.1080/14748460.2012.761816.
- Herrington, Jan. 2009. 'Authentic E-Learning in Higher Education'. In *eLi 2009 Riyadh Conference on E-Learning and Distance Learning*. Riyadh. http://researchrepository.murdoch.edu.au/7254/1/e-learning_in_higher_education.pdf.
- Herrington, Jan, Thomas C Reeves, and Ron Oliver. 2014. 'Authentic Learning Environments'. In *Handbook of Research on Educational Communications and Technology*, edited by J. Michael Spector, M. D Merrill, J Elen, and M. J Bishop, 4th ed., 401–12. New York: Springer Science+Business Media.

- Hung, Woei. 2011. 'Theory to Reality: A Few Issues in Implementing Problem-Based Learning'. *Educational Technology Research and Development* 59 (4): 529–52.
- Joham, Carmen, and Marilyn Clarke. 2011. 'Teaching Critical Management Skills: The Role of Problem-Based Learning'. *Teaching in Higher Education* 17 (1): 75–88. doi:10.1080/13562517.2011.590975.
- Jonassen, David H, and Woei Hung. 2008. 'All Problems Are Not Equal: Implications for Problem-Based Learning'. *Interdisciplinary Journal of Problem-Based Learning* 2 (2): 6–28. doi:http://dx.doi.org/10.7771/1541-5015.1080.
- Kek, Megan Yih Chyn A., and Henk Huijser. 2011. 'The Power of Problem-based Learning in Developing Critical Thinking Skills: Preparing Students for Tomorrow's Digital Futures in Today's Classrooms'. *Higher Education Research & Development* 30 (3): 329–41. doi:10.1080/07294360.2010.501074.
- Lester, Stan, and Carol Costley. 2010. 'Work-based Learning at Higher Education Level: Value, Practice and Critique'. *Studies in Higher Education* 35 (5): 561–75. doi:10.1080/03075070903216635.
- Litchfield, Andrew, Jessica Frawley, and Skye Nettleton. 2010. 'Contextualising and Integrating into the Curriculum the Learning and Teaching of Work-Ready Professional Graduate Attributes'. *Higher Education Research & Development* 29 (5): 519–34.
- Love, Peter, David J Edwards, Sangwon Han, and Yang M Goh. 2011. 'Design Error Reduction: Toward the Effective Utilization of Building Information Modeling'. *Research in Engineering Design* 22 (3): 173–87. doi:10.1007/s00163-011-0105-x.
- Love, Peter, David Edwards, and Elliot Wood. 2011. 'Loosening the Gordian Knot: The Role of Emotional Intelligence in Construction'. *Engineering, Construction and Architectural Management* 18 (1): 50–65. doi:10.1108/09699981111098685.
- Marcelino, Roderval, Juarez Bento da Silva, Gustavo Ribeiro Alves, and Lírio Shaeffer. 2010. 'Extended Immersive Learning Environment: A Hybrid Remote/Virtual Laboratory'. *International Journal of Online Engineering (iJOE)* 6 (5): 46–51.
- Minocha, Shailey, and Ahmad John Reeves. 2010. 'Interaction Design and Usability of Learning Spaces in 3D Multi-User Virtual Worlds'. In *Human Work Interaction Design: Usability in Social, Cultural and Organizational Contexts*, edited by Dinesh Katre, Rikke Orngreen, Pradeep Yammiyavar, and Torkil Clemmensen, 316:157–67. IFIP Advances in Information and Communication Technology. Berlin Heidelberg: Springer. http://dx.doi.org/10.1007/978-3-642-11762-6_13.
- Nadolski, Rob J., Hans G. K. Hummel, Aad Sloopmaker, and Wim van der Vegt. 2012. 'Architectures for Developing Multiuser, Immersive Learning Scenarios'. *Simulation & Gaming* 43 (6): 825–52. doi:10.1177/1046878112443323.
- Newton, Sidney. 2011. 'Building and Construction: Learning and Teaching Academic Standards Statement'. Learning and Teaching Academic Standards Project. Strawberry Hills, NSW: ALTC.
- Nikolic, Dragana, Shrimant Jaruhar, and John I Messner. 2011. 'Educational Simulation in Construction: Virtual Construction Simulator'. *Journal of Computing in Civil Engineering* 25 (6): 421–29.
- Oliver, Martin, and Jen Harvey. 2002. 'What Does "impact" Mean in the Evaluation of Learning Technology?' *Educational Technology & Society* 5 (3). http://www.ifets.info/journals/5_3/oliver.html.

- Orrell, J. 2011. 'Good Practice Report: Work-Integrated Learning'. Strawberry Hills, NSW: ALTC. <http://www.acen.edu.au/resources/docs/WIL-Good-Practice-Report.pdf>.
- Ostwald, Michael J, and Anthony Williams. 2008. 'Understanding Architectural Education in Australasia'. Sydney: ALTC.
- Parton, Graham, and Richard Bailey. 2008. 'Problem-Based Learning: A Critical Rationalist Perspective'. *London Review of Education* 6 (3): 281–92. doi:10.1080/14748460802528475.
- Savage, Susan. 2011. 'Learning and Teaching Academic Standards Statement for Architecture'. Learning and Teaching Academic Standards Project. Strawberry Hills, NSW: ALTC.
- Sheriff, Abdullahi, Dino Bouchlaghem, Ashraf El-Hamalawi, and Steven Yeomans. 2011. 'Information Management in UK-Based Architecture and Engineering Organizations: Drivers, Constraining Factors, and Barriers'. *Journal of Management in Engineering* 28 (2): 170–80. doi:10.1061/(ASCE)ME.1943-5479.0000085.
- Smith, Calvin. 2012. 'Evaluating the Quality of Work-Integrated Learning Curricula: A Comprehensive Framework'. *Higher Education Research & Development* 31 (2): 247–62.
- Tucker, Richard. 2012. 'Collaboration Down Under: Investigating Team Learning in Australia in Architecture and Related Design Contexts'. In *Proceedings of the Canada International Conference on Education (CICE-2012)*, 324–29. Ontario, Canada: CICE.
- Tucker, Richard, and Neda Abbasi. 2014. 'The Architecture of Teamwork: Examining Relationships between Teaching, Assessment, Student Learning and Satisfaction with Creative Design Outcomes'. *Architectural Engineering and Design Management*, June, 1–18. doi:10.1080/17452007.2014.927750.