British Journal of Educational Technology *Vol 46 No 2 2015* 412–422
doi:10.1111/bjet.12135

Virtual reality and learning: Where is the pedagogy?

Chris Fowler

Chris Fowler is a honorary research fellow in the School of Computer Science & Electronic Engineering at the University of Essex. From 2010 t0 2013, he was Professor of Education in the School of Education at the University of the West Indies, where among other things he was responsible for the development and implementation of their Blended Learning Policy. His first degree and doctorate are in Psychology. Before joining UWI, he was a professor and coordinator for Research & Evaluation at the Institute of Distance Education, University of Swaziland. Between 2002 and 2009, he was the professor and director of Chimera, the Institute of Socio-technical Innovation and Research at the University of Essex, and before that he worked for British Telecom's (BT) Research Department, leading their Education and Training Research Team, Asian Research Centre in Malaysia and their Customer Behaviour Laboratory in Ipswich, UK. His current research interests include developing conceptual frameworks to support the design and evaluation of learning systems, learning in virtual reality environments and assessing the impact of educational technologies on the teaching and learning experience. Address for correspondence: Prof Chris Fowler, School of Computer Science & Electronic Engineering, the University of Essex, Wivenhoe Park, Colchester C04 3SQ, UK. Email: cfowler@essex.ac.uk.

Abstract

The aim of this paper was to build upon Dalgarno and Lee's model or framework of learning in three-dimensional (3-D) virtual learning environments (VLEs) and to extend their road map for further research in this area. The enhanced model shares the common goal with Dalgarno and Lee of identifying the learning benefits from using 3-D VLEs. The approach adopted here is to attempt a more pedagogical description using the concept of pedagogical immersion as derived from Mayes and Fowler's framework for mapping stages of learning onto types of learning environment. The paper adopts a "design for learning" perspective and in doing so hopes the combined framework will prove useful to those designing learning activities in 3-D VLEs.

Introduction

The use of virtual reality (VR) technologies for creating learning environments holds great promise but also many challenges. One of these challenges is understanding the pedagogical underpinning that should inform the design and use of these VR systems. Mikropoulos and Natsis (2011) reviewed over 50 papers, spanning 10 years (1999–2009), concerning the use of VR in the design of educational virtual environments (EVE). One of their observations is that very few of the studies reviewed had a clear theoretical (pedagogical) model to inform the use and design of the EVEs. Where a theoretical model is proposed, it is nearly always based on constructivism, often implied, or is a variant of the approach (eg, problem-based learning, experiential learning, collaborative learning). "All the other reviewed articles do not refer explicitly to a learning theory" (Mikropoulos & Natsis, 2011, p. 775).

It is this challenge that Dalgarno and Lee (2010) address in their model of learning in three-dimensional (3-D) virtual environment (VE). This paper, however, argues that Dalgarno and Lee have mainly taken into account the technological perspective, specifically through the identification of learning benefits that arise from the technical affordances implicit in these 3-D learning environments. What is required is a perspective that will focus more on learning outcomes and objectives, and on the kind of learning that any technical environment needs to support. An

Practitioner Notes

What is already known about this topic

- Definitions and descriptions of three-dimensional (3-D) virtual learning environments (VLEs).
- Learning affordances/benefits of 3-D VLEs.
- Constructivist approaches to learning.

What this paper adds

- Pedagogical requirements, models and frameworks.
- "Design for learning" perspective.
- Learning specifications.

Implications for practice and/or policy

- New learning requirements' elicitation and specification methods.
- Need for new design guidelines for building 3-D VLEs.
- Need for new guidance for the effective use of 3-D VLEs in everyday teaching and learning.
- Greater awareness of cultural issues in learning and how 3-D VLEs can address cultural sensitivities.

extension to Dalgarno and Lee's model that takes into account these more pedagogical considerations is therefore offered.

Dalgarno and Lee's (2010) model of learning in 3-D VWs

The three defining characteristics of a 3-D VE for Dalgarno and Lee (2010) are the illusion of three dimensions, smooth temporal and physical changes, and a high level of interactivity (cf. Wann & Mon-Williams, 1996). They supplemented this more behavioural definition by stating that they are "mostly concerned with 3-D virtual learning environments (VLEs) that can be explored using a standard personal computer (PC) commonly available in schools and homes" (p. 11). They note that such desktop environments cannot be fully immersive nor provide a true 3-D experience. Such systems can be more accurately described as desktop semi-immersive VEs to distinguish them from more fully immersive and truly 3-D environments (eg, those found in multiprojected cave automatic virtual environments).

With respect to learning, Dalgarno and Lee argue that "representational fidelity" and "learner interaction" are the two unique characteristics of 3-D VLEs. Representational fidelity refers to the quality of the display, with high-fidelity displays being most realistic or photorealistic. Realism not only refers to the visual qualities of the display but also the consistency of object behaviour, realism of the communication and available actions, and the quality (both behavioural and visual) of the user representation within the 3-D VLE. On the other hand, learner interaction in 3-D VLE is a more dynamic concept describing the richness of different interactions resulting mainly from the degree of embodiment experienced by the user. In 3-D VLE, users have a representation or embodiment through the use of an avatar. The avatar is the user's representation—able to communicate, show emotions, and control and create objects as if the user was actually there or present in the 3-D VLE.

These two unique characteristics of representational fidelity and learner interaction combine to create a particular psychological experience described as a sense of being there or a sense of presence. In a multi-user context, there can also be a sense of co-presence or the "sense of being there together." A third emerging property is identity construction. Identity construction appears to be particular to environments that support some kind of user representation, normally embodied in an avatar. The avatar is the user's representation within the virtual world (VW) and through its appearance and actions becomes identified with the actual user. Clearly, the existence of avatars physically representing users within the VLE can also contribute to the sense of presence and co-presence. Avatars, however, are only found in VWs and not in all 3-D VLEs.

The question arises whether these user experiences actually result in any learning benefits. To answer this question, Dalgarno and Lee review examples of VLEs to identify five key task affordances (ie, functional properties) that can benefit learning. The five affordances or benefits are spatial knowledge representation, experiential learning, engagement, contextual learning and collaborative learning. These five affordances directly translate into learning benefits (see Figure 1).

Some readers may interpret Dalgarno and Lee's model (see Figure 1) as implying that higher levels of representational fidelity and learner interactions will lead to deeper learner experiences

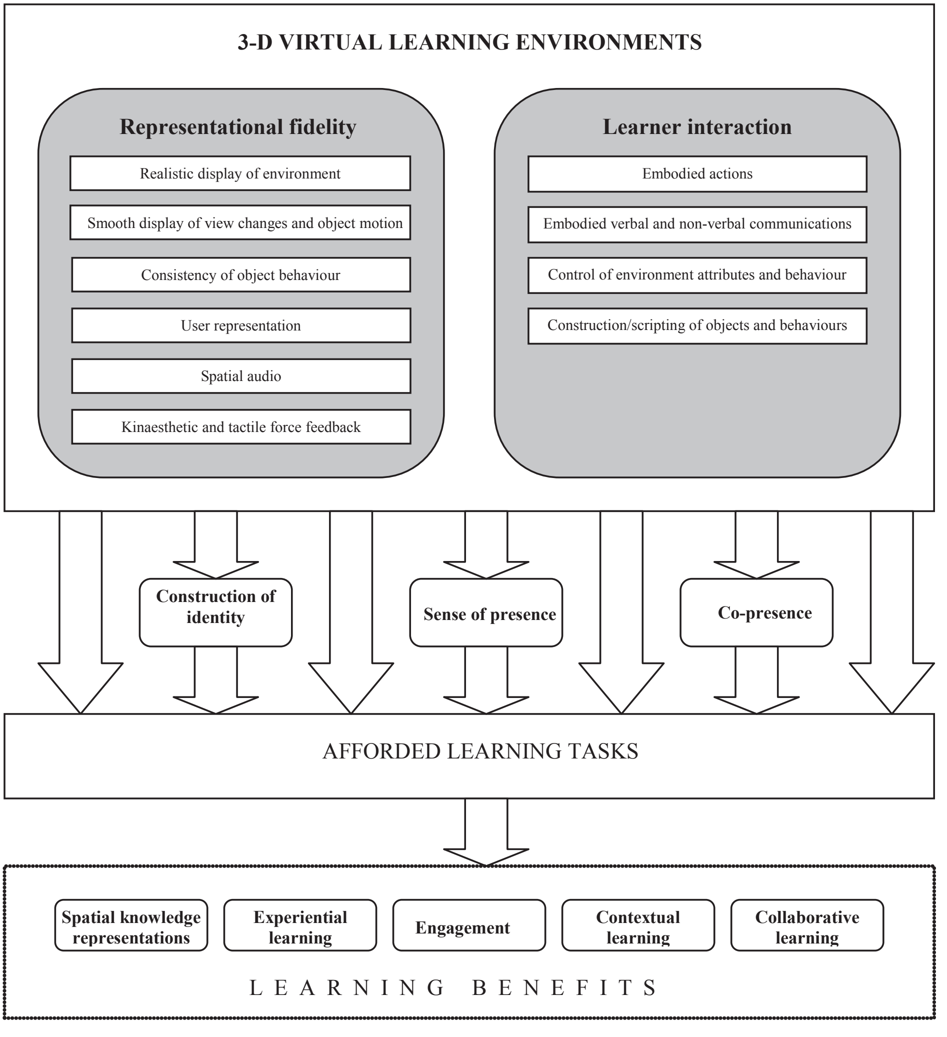

Figure 1: Dalgarno and Lee's elaborated model of learning in a 3-D VLE

and benefits. However, the assumption that high levels of representational fidelity and learner interaction will result in deeper learning is questionable. It may be argued that there are optimum levels of these characteristics that maximise learning. Going beyond the optimum increases costs and results in a limited or even negative return with respect to learning benefits (an "inverted U" effect, cf. Yerkes-Dodson Law [Yerkes & Dodson, 1908]).

There may also be circumstances when a continuum may not be relevant. Not all learning contexts, for example, may require realistic feedback or spatial audio. As a practitioner, therefore, the decision may not only be about selecting the optimum point on a continuum but also whether the continuum needs to be considered at all. The practitioner must design a specific learning experience that best meets the pedagogical needs of the learner. This requirement introduces a more dynamic component to the model. For example, there may be a trade-off between photorealism and behavioural realism, and the optimum combination may well change according to the learning context. A 3-D VLE designed to illustrate how the different physical states of water (solid, liquid or gas) change with increasing temperature really does not require photorealistic representations of the different states but does demand behavioural consistency so the objects change to the right state at the right temperature.

Even altering the temperature in the above example can be done simply and does not require "kinaesthetic and tactile force feedback." A more collaborative task, where learners decide collectively what temperature level to choose or where they can discuss the impact of the changes on the physical state of the object, does not require "spatial audio" and indeed simple "text chat" would suffice in these circumstances. In this particular example, the issue of embodied actions and communication also comes into question. The user can be an external viewer able to change their viewpoints or perspectives, and communicate without the necessity of having a representation (eg, an avatar) within the 3-D VLE. It would be possible to redesign the system to include avatars, but the question remains—what value or benefits would this add to this particular learning experience?

Furthermore, the three characteristics of the learner's experience, that is, the construction of identity, sense of presence and that of co-presence by Dalgarno and Lee do not, at least directly, describe a learning experience. Whether or not you can construct an identity or have a sense of presence or co-presence will affect the experience but does not describe the experience itself.

Lee, Wong and Fung (2010) adopt a more "process" approach to describing the learning experience, based on Salzman, Dede, Loftin and Chen (1999), stressing the input, mediating, moderating and output variables of the learning process. Mediating between the VR features (eg, representational fidelity) or independent variables and the learning outcomes (eg, performance) or dependent variables are two sets of mediator variables, one of which is the "learning experience" and the other "interaction experience" (eg, usability). They also include moderator variables that reflect individual differences in student characteristics (eg, learning styles) that can moderate (positively or negatively) the learning experience. Lee *et al* generated a number of hypotheses based upon their model and tested them using a VR programme on students with a range of different characteristics. They found significant evidence to support their model. However, the VR programme used was a simulation (a virtual frog), was not immersive and involved no avatars.

Extending the model

What is required to fully describe the learning experience is a framework that is not solely derived from technological affordances but also includes pedagogical requirements. These requirements should also inform the design of the learning experience. One concept that may bridge the pedagogy with the technology is the notion of "immersion." Dalgarno and Lee agree with Hedberg and Alexander (1994) that one conception of immersion arises from a complex interaction of representational fidelity and learner interaction. It is therefore not a unique property because it results from the interaction of two other properties. Immersion, therefore, is a more technical description of the properties arising from the immersive system. In contrast, "presence" is the psychological state that can arise from an immersive system. It could be argued that another concept of immersion will also emerge from a complex interaction of different pedagogical variables, in other words, the pedagogical state that arises from learning within an immersive system.

Immersion provides, therefore, a concept that can bridge both the technological, psychological and pedagogical experiences of learning in a 3-D VW. The framework described by Mayes and Fowler (1999) offers a principled way of relating a concept like immersion to those contrasting ways of understanding a learning experience. This framework was designed to be used by practitioners because it simplifies the complexity of learning at the psychological level into three fundamental stages. These are called conceptualisation, construction and dialogue by Mayes and Fowler and are mapped onto three kinds of what in 1999 was termed "courseware." This term encompasses both the pedagogical and technological dimensions of what we now describe as a learning environment.

In this framework, then, a learning experience is characterised in one of three ways. First, a learner will encounter some kind of explanation or description that provides the opportunity for a new concept to be created. In the case of skill learning, this stage will demonstrate in some way what is to be learned; in the case of conceptual learning, an initial understanding of the concept will be formed. This kind of learning maps onto what Mayes and Fowler called "primary courseware": a presentation to the learner, equating to traditional forms of instruction, such as lectures or textbooks, but including multimedia representations that can provide high fidelity. In our current terms, the presentation can allow the learner to be immersed in this primary representation of the concept or concepts. An example might be the presentation of different states of an entity through the observation of physical, molecular or atomic representations.

Second, learners must, in order to deepen their understanding, start to explore, manipulate or ask questions, and this means they must perform some actions on, or with, the new concept in a way that will provide feedback. This stage—construction—requires an interactivity that traditional instruction offers through such methods as field and laboratory studies, or even through essay writing. Environments that support this kind of learning are called by Mayes and Fowler "secondary courseware": secondary in the sense that the learner's actions now control the flow of information. The immersion is now in the task, rather than in the representation.

Third, to acknowledge that all learning is in some way situated in a wider social context, Mayes and Fowler defined a third stage of learning as dialogue, in which the learner may test their emerging understanding through some kind of interaction or discussion with others. Traditionally, this stage is supported by a tutorial. Environments that specifically support dialogue are called "tertiary courseware" to indicate their use at a stage subsequent to the building by the learner of an understanding or level of skill sufficient to sustain a dialogue. We can see that avatars might play a highly facilitative role at the stage of dialogue, in role playing for example, as well as in supporting a prior explorative task.

The question, then, is whether a 3-D VLE can create new learning experiences that still address these key stages of learning. The word "new" is important as these innovative technologies should not necessarily be used to "emulate" current practices, but, where possible, to innovate new, pedagogically sound practices. One risk with high-fidelity 3-D VLEs is that they will be used to create virtual classrooms that "feel" and look like real classrooms but lose the opportunity to create pedagogically new and innovative learning environments.

The framework described above offers one of the few conceptual tools specifically created to support the design of learning systems (see, for example, Gardner, Fowler & Scott, 2003) driven by pedagogical rather than technological considerations. Both Dalgarno and Lee's and Lee *et al*'s models begin with technical affordances to derive learning benefits or outcomes. Mayes and Fowler, on the other hand, begin with pedagogical "affordances" to design the technology to maximise the learning outcomes.

In the 3-D VLE context, each of Mayes and Fowler's stages could be associated with different learning experiences, all of which share the common factor of being "pedagogically immersed" or "presence pedagogy" (Bronack *et al*, 2008). Each of the three learning stages (conceptualisation, construction and dialogue) can be associated with different types of immersion (conceptual, task, and social), and these interact with the emerging properties of the technical characteristics of 3-D VLEs. Conceptual immersion in Mayes' framework is characterised by a space designed to represent mainly abstract concepts (at least in a higher education context) in which users can interact and change views and representations of the concepts (eg, an exploration of different states of an entity, through the observation of physical, molecular or atomic representations). In these circumstances, the use of an avatar can be very powerful for allowing a self-directed exploration of the different representations (ie, moving in and around different molecules). In task immersion, there is a much higher degree of realism and levels of manipulation, and experiential learning is a key attribute. The role of avatars, although not essential, can certainly enhance task immersion by supporting activities like role playing. The use of avatars in social immersion is even more self-evident and indeed represents one of the primary purposes for the creation of avatars.

The problem with using the term "immersion" is that it is being used both technologically, psychologically and now pedagogically. To avoid this and to use terms more on a par with Dalgarno and Lee's "construction of identity," "sense of presence" and "co-presence," the terms "empathy," "reification" and "identification" are suggested. In conceptual immersion, the ability to identify and empathise with the concept is critical to understanding it. Likewise, the ability to make the concept more concrete (reification) is a key component to task immersion (cf. Winn, 2005). Finally, Mayes and Fowler's dialogue stage depends on learners having a deep enough understanding of concepts to allow them to engage in thoughtful and structured argument and discussion that reflect a certain level of expertise and "identification" with the subject matter (cf. Fowler & Mayes, 1999).

Figure 2 is an attempt to extend and enhance Dalgarno and Lee's model to include a stronger pedagogical input and a design emphasis. The approach adopted is very much a practitioner-orientated one by helping guide the practitioner to consider how a 3-D VLE can be designed to meet his or her particular teaching and learning requirements. Both sides of the model (Dalgarno and Lee, and Mayes and Fowler) are united by a common need to create or expose the learner to an experience that meets the intended learning outcomes (ILOs) One key addition, therefore, is to ensure that the ILOs are defined. ILOs are what learners are expected to know, understand and be able to do by the end of the learning experience (see Biggs, 2003).

Mayes and Fowler's framework in the extended model specifies the pedagogical or learning requirements for the different learning stages. These can be matched to the technology affordances offered by 3-D VLEs (eg, Dalgarno and Lee). Combining or matching of the task affordance with learning requirements is seen as a central component of another unifying concept, that is, "design for learning." Design for learning is different from a learning design or designing an e-learning system. It is more concerned with a holistic activity of designing and planning activities as part of a particular learning session or course defined by a set of specific learning outcomes (cf. Sharpe & Oliver, 2007). In contrast, "learning design" has become associated with a particular systematic approach (IMS Learning Design or IMS-LD) or language (Educational Modelling Language) to describe the specification of learning activities (see Britain,

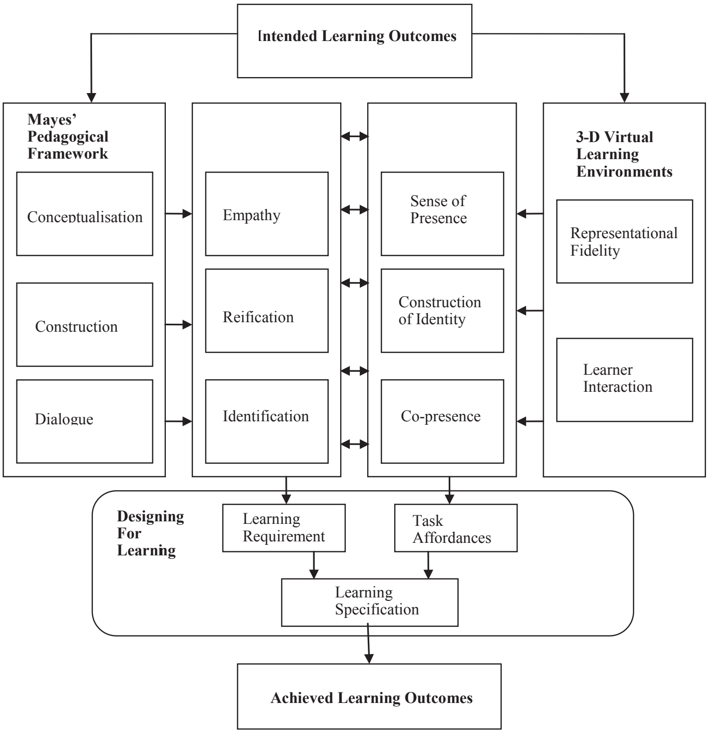

Figure 2: An enhanced model of learning in 3-D VLEs

2004). Fowler, van Helvert, Gardner and Scott (2007) also note a third use of learning design and that is the design of e-learning systems (a specialised form of system design). Within the "design for learning" context, learning requirements are similar to Dalgarno and Lee's learning benefits. They can be divided into generic and specific requirements. For example, "engagement" is a generic requirement—all learning activities should be engaging, whereas "spatial knowledge representation" is more specific and will apply to only some learning activities.

Fowler and Mayes (2004) argue that the learning requirements are best described as generic learning activities based on Bloom's (1956) taxonomy. This approach is not dissimilar to using the revised and updated version of Bloom's taxonomy (Anderson *et al*, 2001). Anderson *et al* created a taxonomy table from mapping the cognitive process dimension of creating, understanding, analysing, applying, understanding and remembering onto a knowledge dimension (metacognitive, procedural, conceptual and factual). Where the two dimensions intersect, a learning objective can be identified. For example, the learning objective that is associated with the metacognition and evaluate dimensions is "reflect." The object of the verb (what is being reflected on) is determined by the particular learning domain, problem or context. As Anderson *et al* recognise, a learning objective (what is to be learnt) is not the same as a learning activity (how it is learnt). Table 1 shows a similar process but where learning activities (see Conole, Dyke, Oliver & Seale, 2004), can be derived from Mayes and Fowler's learning stage through specifying the appropriate learning objective (based on Bloom's revised taxonomy). Specifying learning activities is seen as an important component of a design for learning approach (cf. Beetham, 2007).

Fowler and Mayes (2004) further argue that the learning requirements need to be understood within a particular learning context. The learning context should include such variables as:

Table 1: Deriving learning activities

Learning stage (based on Mayes & Fowler's, (1999) framework)	*Learning outcomes/ objectives (based on Bloom's [revised] taxonomy)*	*Learning activities (based on Conole et al's, (2004) mini-learning activities)*
Conceptualisation	Exposing learners to new concepts, theories and facts	Receiving information, scoping domains, identifying boundaries, generalising from given facts
	Gathering facts/concepts	Gathering resources, brainstorming a concept, discovering facts, interpreting facts, classifying facts
	Presenting and explaining facts or concepts	Ability to organise and present material in a timely, logical and coherent way
Construction	Evaluating facts/concepts	Developing values, synthesising of key findings from a range of resources, ranking and rating a set of values, making judgements, making comparisons, interpreting facts, recognising subjectivity
	Building/testing/applying theories/concepts	Recognise patterns, draw conclusions, predict outcomes, construct models, follow instructions, apply knowledge, demonstrate outcomes, plan experiments, state rules
	Solving/analysing problems	Investigate a problem; analyse wholes into parts; synthesise parts into wholes; apply principles; select effective solutions; use methods, concepts, theories in new situations
	Acquiring skills	Sequence parts, practice sequences
	Acquiring and applying knowledge to perform in real world settings	Observing, analysing and reflecting upon other people's real world behaviours and then practicing those behaviours in real world settings
Dialogue	Reflecting critically	Self-assessment of level of competence, critique own performance, recognise own limitations
	Engaging in discussion	Defend a position, set up teams of learners, establish different roles in a team, discussion, share ideas and come up with a combined list

- Locus of control (the teacher or learner?)
- Group dynamics (individual or group?)
- Teacher dynamics (one to one, one to many, many to many?)
- Activity or task authenticity (realism?)
- Level of interactivity (high, medium or low?)
- Source of information (social, reflection, informational, experiential?)

These contextual variables combined with the learning requirements help configure the most appropriate teaching and learning approach that could be adopted by the practitioner (see Fowler & Mayes, 2004). For example, the "instruction" approach is teacher centric with an emphasis on orientating learners and introducing new concepts, with learners having a relatively passive role. In contrast, a more "social construction" approach depends on learners working in groups relying on social processes to support and benefit individual activities. The choice of approach will, in turn, help inform the learning specification (see Figure 3). Designing for learning, therefore, is envisaged as a process that goes from a general contextual description of the teaching and learning environment through a set of teaching and learning requirements based on defining what stage the learner is at and what learning outcomes have to be achieved by undertaking a given set of learning activities. The practitioner then has to determine a particular teaching and

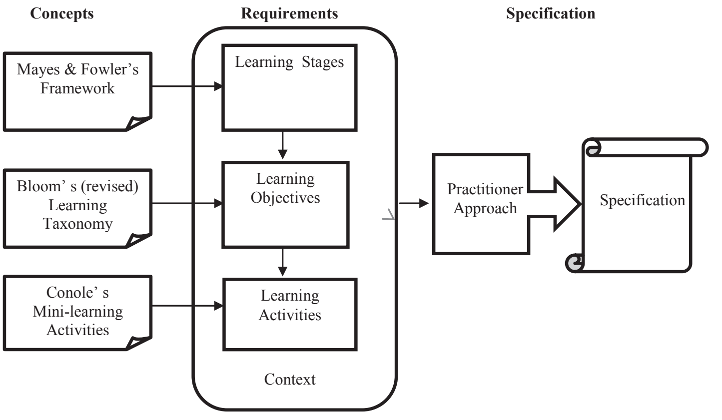

Figure 3: A "design for learning" approach

learning approach that can best meet the requirements. The whole process can then be recorded in a learning specification. Exactly how a learning specification is presented will vary. Looser specifications include storyboards (eg, Marie & Klein, 2008), moving to tighter uses (eg, templates or tables) to very formal learning specifications (eg, IMS, 2003).

An alternative approach is to begin with a scenario that provides a description of the proposed user, the learning experiences and the learning technologies in a natural language format. The description is then analysed in detail to elicit the learning needs and requirements (see Van Helvert & Fowler, 2004). Once the requirements have been stated, then an appropriate practitioners' approach that best meets the requirements can be selected. Regardless of the approach adopted, the key message is that designing for learning must explicitly incorporate pedagogical considerations into their specification of a technology-enhanced learning experience.

The design approach described above is essentially generic and assumes that certain kinds of decisions have already been made. For example, the approach assumes that a VW is an appropriate technical solution (based on Dalgarno and Lee's learning benefits) and that the learning outcomes have been correctly identified and specified. When applying this approach, other higher and lower level decisions also need to be made. The higher level design decisions mainly concern issues of how much of the learning or teaching experience will take place in the VW. A blended approach, for example, will result if the designer chooses a mix of virtual and real world educational experiences. For instance, a designer of a VW to support the teaching and learning of chemistry may decide only to use a VW solution for the laboratory work and to retain face-to-face teaching for all other aspects. Equally low-level implementation decisions are not addressed in the proposed approach. Examples of a lower level decision could be about the specific choice of examples, activities and objects to be included in the VW. This level of decision making is important in helping to ensure that authentic or culturally relevant teaching and learning take place.

Further research

The extension of Dalgarno and Lee's model to include more pedagogical components provides an important bridge between the technology and learning theory-centred approaches to the design of educational VWs. There is an imperative to move away from research that starts with an analysis of the technology then seeks to derive learning benefits, often from loosely defined or implicit learning approaches (particularly constructivism). The extended model should not only enrich our conceptual understanding of learning in VWs but also provide a common framework and language that can be used by, for example, teachers, designers and theoreticians. Future collaboration between these and other stakeholder is likely to be one of the keys to advancing this area of research.

Dalgarno and Lee make the case for more research to empirically establish the validity of their framework. This is an important first step that should be followed by similar research into the effectiveness of the enhanced Mayes and Fowler's framework for designing pedagogically sound 3-D VLEs. More applied research is needed to focus on eliciting the learning requirements from sound pedagogical models and frameworks, and then to seek evidence of technological support, and, if necessary, to identify areas for future developments from requirements that are not met by the existing technology. Only through its rigorous and extensive application will the value of the model to practitioners and academics alike be determined.

Also, more research is needed to explore the effectiveness of different types of learning specifications (ie, scenarios, storyboards) in general, and in particular, looking at how to use learning designs (eg, IMS-LD) to more formally specify learning activities within a 3-D VLE. The work of Perez-Sanagustin *et al* (2008) looks particularly promising in this respect by incorporating dialogue into a dynamic and configurable template able to run on the IMS LD players.

Bringing the two frameworks together and testing the combined framework is more difficult. As Dalgarno and Lee note, it is difficult and some would say impossible (see Clark, 1994) to separate the technology from the pedagogy. However, some light can be shed on the individual contributions by comparing studies that retain the existing pedagogy but deliver it using new technology (eg, replacing whiteboards with smart boards in an essentially "talk and chalk" teaching approach) against those that change the pedagogy and the technology (for example, moving to a more constructive paradigm through using 3-D VLEs). Finally, there may be situations where the technology remains constant, but the teaching and learning approaches change. Ironically, this often results from practitioners "rediscovering" pedagogy as a result of using technology and then applying it to their more traditional face-to-face teaching. In such comparisons, the subject matter and learning outcomes must be kept constant as well as the method of measuring the achieved learning outcome (the impact on academic performance). Care must also be taken to control and/or reduce novelty and placebo effects.

Dalgarno and Lee also stress the importance of "establishing guidelines and best practice." This position is reinforced by the stronger design and practitioner orientation of the new combined framework. The principles and practices of the combined framework must be presented in a way that practitioners can understand and apply them in their teaching and learning. Although guidelines exist to support the design of VR military applications (eg, Dixon, Fitzhugh & Aleva, 2009) and the design of the buildings and other objects within the VWs (eg, Saleeb & Dafoulas, 2011), more work is required in creating guidelines for educational applications and more critically for evaluating their acceptability and effectiveness.

Acknowledgements

The author would like to thank Barney Dalgarno and Mark Lee for giving permission to reproduce Figure 1 from their 2010 publication, and Michael Gardner and Terry Mayes for their thoughtful and useful comments on various drafts of the paper.

References

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R. *et al* (2001). *A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives*. New York: Longman.

Beetham, H. (2007). An approach to learning activity design. In H. Beetham & R. Sharpe (Eds), *Rethinking pedagogy for a digital age: designing and delivering e-learning* (pp. 26–41). London: Routledge.

Biggs, J. B. (2003). *Teaching for quality learning at university*. Buckingham: The Open University Press.

Bloom, B. S. (Ed.) (1956). *Taxonomy of educational objectives: the classification of educational goals*. New York: Longman.
Britain, S. (2004). *A review of learning design: concept, specifications and tools*. A report for the JISC E-learning Pedagogy Programme. Retrieved September 30, 2011, from http://www.jisc.ac.uk/index.cfm?name=project_elearn_ped_learning_design_tools
Bronack, S., Sanders, R., Cheney, A., Reidl, R., Tashner, J. & Matzan, N. (2008). Presence pedagogy: teaching and learning in 3-D immersive environments. *International Journal of Teaching and Learning in Higher Education*, *20*, 59–69.
Clark, R. E. (1994). Media and method. *Educational Technology Research and Development*, *42*, 7–10.
Conole, G., Dyke, M., Oliver, M. & Seale, J. (2004). Mapping pedagogy and tools for effective learning design. *Computers & Education*, *43*, 17–33.
Dalgarno, B. & Lee, M. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology*, *41*, 10–32.
Dixon, S., Fitzhugh, E. & Aleva, D. (2009). Human factors guidelines for applications of 3D perspectives: a literature review. SPIE Defence, Security, & Sensing 2009, Orlando, FL, 13–17 April.
Fowler, C. J. H. & Mayes, J. T. (1999). Learning relationships from theory to design. *Association for Learning Technology Journal*, *7*, 6–16.
Fowler, C. J. H. & Mayes, J. T. (2004). JISC e-learning model desk study. Stage 2: mapping theory to practice and practice to tool functionality based on a practitioners' perspective. JISC. Retrieved October 15, 2011, from http://www.jisc.ac.uk/uploaded_documents/Stage%202%20Mapping%20(Version%201).pdf
Fowler, C. J. H., Van Helvert, J., Gardner, M. R. & Scott, J. R. (2007). The use of scenarios in designing and delivering learning systems. In H. Beetham & R. Sharpe (Eds), *Rethinking pedagogy for a digital age* (pp. 129–142). London: Routledge.
Gardner, M., Fowler, C. & Scott, J. (2003). A process for bridging technology and pedagogy for the design of e-learning systems. Online Educa Conference proceedings, Berlin, December 2003.
Hedberg, J. & Alexander, S. (1994). Virtual reality in education: defining researchable issues. *Educational Media International*, *31*, 214–220.
IMS (2003). *Learning Design Best Practice and Implementation Guide*. IMS Global Learning Consortium Inc. Retrieved September 15, 2010, from http://www.imsglobal.org/learningdesign/ldv1p0/imsld_bestv1p0.html
Lee, E. A., Wong, K. W. & Fung, C. C. (2010). How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach. *Computers & Education*, 55, 1424–1442.
Marie, G. & Klein, J. (2008). Developing effective detailed design documents and WBT/CBT storyboards. In C. Bonk, M. Miyoung Lee & T. Reynolds (Eds), *Proceedings of world conference on e-learning in corporate, government, healthcare, and higher education 2008* (pp. 1820–1825). Chesapeake, VA: AACE.
Mayes, J. T. & Fowler, C. J. H. (1999). Learning technology and usability: a framework for understanding courseware. *Interacting with Computers*, *11*, 485–497.
Mikropoulos, T. A. & Natsis, A. (2011). Educational virtual environments: a ten-year review of empirical research (1999–2009). *Computers & Education*, *56*, 769–780.
Perez-Sanagustin, M., Hernandez-Leo, P., Santos, P., Sayago, S., Griffiths, D. & Blat, J. (2008). Dialogic learning and interactive groups: an IMS LD template integrated in run-time systems. *Int. Journal of Emerging Technologies in Learning*, *3*, 38–45.
Saleeb, N. & Dafoulas, G. (2011). Effects of virtual world environments in student satisfaction: an examination of the role of architecture in 3D education. *International Journal of Knowledge Society Research*, *2*, 29–48.
Salzman, J. G., Dede, C., Loftin, R. B. & Chen, J. (1999). A model for understanding how virtual reality aids complex conceptual learning. *Presence: Teleoperators and Virtual Environments*, *8*, 293–316.
Sharpe, R. & Oliver, M. (2007). Designing courses for e-learning. In H. Beetham & R. Sharpe (Eds), *Rethinking pedagogy for a digital age* (pp. 41–52). London: Routledge.
Van Helvert, J. & Fowler, C. (2004). Scenarios for innovation (SUNA). In I. Alexander & N. Maiden (Eds), *Scenarios and use cases stories through the system life-cycle* (pp. 61–73). London: Wiley.
Wann, J. & Mon-Williams, M. (1996). What does virtual reality NEED? Human factors issues in the design of three-dimensional computer environments. *International Journal of Human–Computer Studies*, *44*, 829–847.
Winn, W. (2005). What we have learned about VR and Learning and what we still need to study. In Proceedings of Virtual Reality International Conference Laval Virtual, Laval, France, pp. 8–17.
Yerkes, R. M. & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*, 459–482.