Anchored BIM Instructional Model for Construction Management Education

ABSTRACT

The growing adoption of BIM in the construction industry is triggering a paradigm change for construction management education. As more design and construction firms integrate BIM into their practices, they would expect the new labour force to be able to document, communicate and collaborate with BIM. Thus, construction educators should prepare graduates with practical skills of BIM. This study aimed to develop and test an anchored BIM instructional strategy, which simulates realistic situations to support students in learning how to utilise BIM to resolve real-world construction management problems. The effectiveness of the new pedagogical model was measured through a questionnaire survey. The results indicate that the anchored BIM instructional method facilitated for students active knowledge construction, in that, learning not only demonstrated knowledge for understanding particular issues but, and more importantly, informed how that knowledge can be used in practice.

Keywords: Construction management education, Building information modelling, Pedagogy, Anchored instruction

INTRODUCTION

Building information modelling (BIM) is an emerging paradigm and a buzzword in today's construction industry. The benefits of BIM have been well researched and established as enhancing project performance, documentation, collaboration and communication among project stakeholders (Eastman *et al* 2008; Krygiel & Nies 2008). Many professional and industry bodies have published BIM guides and contract forms to enable the industry to adopt BIM and benefit from its technological abilities (Sacks & Barak 2010; Kim 2012). However, a lack of personnel with BIM skills has been a major constraint retarding the use of the technology in industry. A survey of BIM use found that a lack of adequate training was the most significant impediment to BIM adoption (Young *et al* 2008). It was further confirmed in another study that a lack of knowledgeable practitioners who are ready to move the industry into the BIM age is a major bottleneck (Hartmann & Fischer 2008). Hence, the construction industry needs far reaching education and training programs if BIM is to achieve widespread adoption (Sacks & Barak 2010).

Many design and construction companies have embarked on the mission to retrain their experienced employees in the use of the new tool for design and delivery of construction projects. Because BIM requires a different way of thinking about how designs are developed and construction is managed, retraining requires not only learning but also

unlearning old habits and thinking, which is difficult (Eastman et al 2008). New graduates whose construction management education was influenced by BIM are likely to have a profound impact on the successful deployment of BIM in the industry. Design and construction companies therefore expect the new labour force be able to design, communicate, collaborate and manage with BIM technologies that are 3D, 4D and 5D (Kim 2012). This new demand sends a strong message to construction educators that they should prepare graduates with practically applicable knowledge and skills around BIM integrated construction management. Specifically, educators should develop curriculums and learning tasks that simulate practical situations to support students in learning how to utilise BIM to resolve real-world construction management problems (Peterson *et al* 2011). Moreover, Woo (2006) highlighted that properly structured BIM courses that provide industry-required knowledge would lead to successful careers in the industry for graduates.

Traditionally, the process of teaching and learning is considered as inert activities that focus more on knowing what but less on knowing how (Brown *et al.* 1989). This teaching philosophy is criticised for easily leading to unmotivated learning and thus unsatisfied learning outcomes (Zydney *et al.* 2012). It is increasingly recognised that knowledge learning is a proactive process that needs to be incorporated into practical situations – activities and contexts where the knowledge is obtained and used; this is called situated cognition (Brown *et al.* 1989). Derived from this concept, anchored instructional strategy was proposed by the Cognition and Technology Group at Vanderbilt (1990) as a specific teaching method which endeavours to create a visual context for a particular problem. It is considered that situating knowledge in specific contexts or learning anchors helps better inform students how knowledge is used in practical situations and therefore produce better learning outcomes (Williams 1992). Hence, this study aimed to develop and test an anchored instructional strategy for BIM-integrated construction management education.

THE CONCEPT OF ANCHORED INSTRUCTION

Anchored instruction was proposed to overcome the problem of inert knowledge learning, which results in a separation between knowledge and its use in real life for problem solving (Cognition and Technology Group at Vanderbilt 1990; Dickinson & Summers 2010). It evolved from the idea put forward by situated cognition which highlights the situated nature, that is, context specific feature of knowledge (Brown *et al.* 1989). While the concept of situated cognition has accentuated the importance of context in learning, anchored instruction is more proactive in creating contexts – for teachers and students to explore specific issues rather than only takes account of the context issue. Specifically, the context for anchored instruction is created in visual formats instead of textual

formats for the reason that the former allows students to develop the skill of pattern recognition, provides greater potential for noticing and facilitates multiple coding in memory, while the latter is considered as often denoting the writer's pattern recognition outputs (Cognition and Technology Group at Vanderbilt 1990). Therefore, by creating specially tailored realistic and interesting visual contexts, anchored instruction encourages students to achieve an active knowledge construction (Love 2004-2005). Consequently, in the process of anchored instruction, teaching and learning not only demonstrate knowledge for understanding particular issues but also, and more importantly, inform how that particular knowledge can be used to deal with problems in practice.

Apart from creating specific contexts and scenarios, anchored instruction is also considered as an important approach to active learning which in particular stresses the importance of active involvement of learners, either mentally or physically, to achieve meaningful learning (Hativa 2000). While it is recognised that human learning involves inputs from all five senses, it has found that knowledge acquisition is mostly achieved through visual stimulation which contributes to 83 per cent of knowledge obtained. Furthermore, with a combined use of audio and visual inputs, more information can be obtained and it has also found that there is a better memory retention rate for that information than if these input methods are used separately (Chen *et al.* 2010). From this perspective and with the increasing application of video and multimedia computing technologies in anchored instruction, it can be said that this teaching method is able to better elicit students' problem-solving goals and methods to solve problems (Shyu 2000).

There are three different instructional sub models, depending on the extent of teacher's involvement in this process: guided-generation model, basic first model and structured problem solving model (Cognition and Technology Group at Vanderbilt 1992).

- Guided-generation model constitutes the most open-ended approach in which the teacher only provides scaffolding support to students and cooperative groups are often established for students to conduct generative activities to solve problems.
- Basic first model proposes that students need to acquire necessary sub skills and sub concepts before they can proceed to apply skills to deal with practical issues. The teacher acts more as a knowledge provider who structures the solutions to problems directly rather than to provide facts to assist students to solve problems.
- Structured problem solving model focuses on helping students to minimise errors and feelings of confusion. In this model, the teacher provides all possible plans for problem solving and guides the student throughout the process to find solutions for problems. Therefore, it lies

between the other two models in terms of the intervention by teachers in guiding the problem solving process.

Technologies for Anchored Instruction

The central focus of anchored instruction strategy is the creation of learning contexts in visual format. Different multimedia and computing technologies can be used to achieve this in practice, as expounded below.

1. Videodisc Programs:

Videodisc programs provide a visual scenario to students, as an adventurous story of a third person, with practical problems that need to be solved being embedded in the programs. Three classical examples for this form of anchored instruction are: the Jasper Series, Encore's vacation and video-centred engagement.

2. Web-based Video Cases:

Web-based video cases were developed in an anchored instruction research project by Sanny & Teale (2008) to investigate how this method can be used to improve literacy teaching and learning experiences. The web system featured an interface and a case-based contents library. The system facilitated for students reflection, constructive exploration and communication with others, including teacher-student messages. The system also allowed users to edit videos, for instance, segment, email part of the videos and create videos for discussion and presentation. The research further showed that the use of web-based video cases by professors in their courses to provides virtual and real environment for learning produced positive impacts on students (Sanny & Teale 2008).

3. Web3D:

Web3D is the concept of interactive 3D contents as displayed via the internet with an overall aim of making the user experience better. Web3D was used in a learning case where students needed to understand the history and culture of a city by exploring an immersive website, called the Forbidden City (Chen *et al.* 2010). In this particular case, students were firstly given problems that they needed to explore and solve. They were then encouraged to work in groups, gather information by exploring the immersive city and solve the problems. The approach fostered an active knowledge learning experience, working as a group.

Critical Success Factors for Anchored Instructional Design

McLarty *et al.* (1989) articulated seven principles to guide the design of anchored instructional curriculums:

1. Choosing an appropriate anchor - this involves deciding on the educational goals and based on which to identify possible anchors that may work for a particular group of students.
2. Developing shared expertise around the anchor - this means that students are given the opportunity to view segments of an anchor, comprehend, organize information and increasingly improve their experiences within the curriculum.
3. Expanding the anchor - if one anchor is insufficient to achieve the education target, additional anchors may be used to help students to better comprehend the subject.
4. Using knowledge as a tool - once students have acquired the knowledge, it is important to allow for an understanding of how to use it. Therefore in this process, students should be given a chance to apply what they have learnt.
5. Teaching with the anchor - teachers need to consciously tie the anchor to the education goals so as to increase students' ability to apply what they have learnt in the anchor to reach their learning objectives.
6. Merging the anchor - students should be able to use their previous knowledge and skills when learning through the anchor so that they can become more active learners.
7. Allowing student to exploration – allowing students to explore the anchor can help develop a sense of expertise and enables knowledge sharing on individual topics.

In short, these principles mean that the anchored instruction requires a specially tailored teaching content/anchor that meets the learning objectives and suits the needs of the students as well.

RESEARCH METHOD

The study adopted action research approach, which is a systematic process that allows educators to try out different ways of doing things in the classroom, until they find something that really works for them and students (Laycock & Long 2009). Mertler & Charles (2008) argued this approach is more practical for lecturers as it: (1) deals with their own problems, not someone else's; (2) can start whenever they are ready—providing immediate results; and (3) provides them with opportunities to better understand, and therefore improve their educational practices.

Action research involves four distinct stages in a closed loop, as shown in Figure 1. The author traversed through these stages in undertaking the

research. First, the author learnt anchored instruction and how ICT might be utilised to aid it. Then, he designed and implemented an anchored instructional model in his course. Next, he conducted a questionnaire survey and data analysis to assess the effectiveness of the new pedagogical model, and finally reflected upon the new practice.

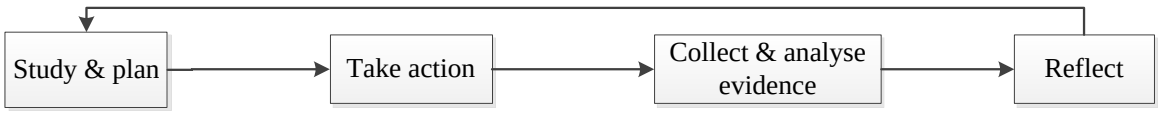


Figure 1: Action research cycle. *Source:* Adapted from Riel (2011)

DEVELOPING AND IMPLEMENTING AN ANCHORED INSTRUCTIONAL MODEL FOR BIM EDUCATION

Three forms of anchored instruction were identified above: guided generation model, basic first model and structured problem solving model. This study experimented with the structured problem solving model as it takes a balanced position between a complete open-ended approach and a complete structured knowledge provider approach. An anchored instructional strategy was infused into the author's course, ICT Applications in Construction, in Construction Management Degree. The course largely covered the use of BIM for construction management.

An anchored instructional model for the course consisted of three components, as shown in Figure 2, namely: anchored learning assignment task; BIMPedia, a web-based video resources platform; and scaffolding lectures and tutorials. The primary element of the instructional strategy was the anchored learning assignment task that drove the instruction and the other two were supportive elements. The contents and formats of these individual elements are described below.

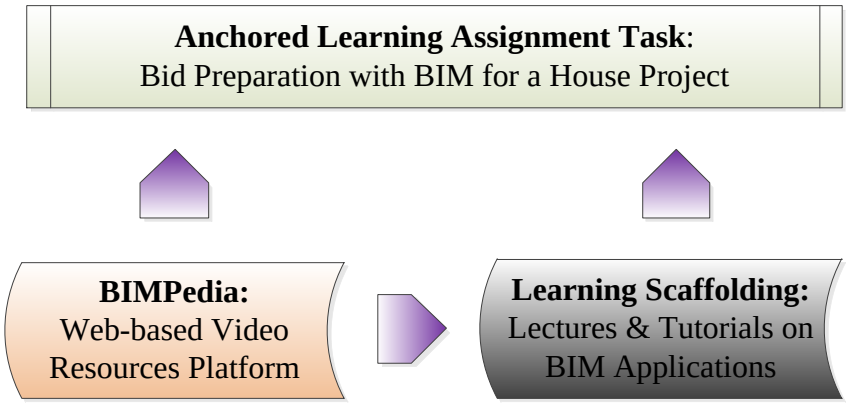


Figure 2: Anchored instructional model for BIM education

Anchored Learning Assignment Task

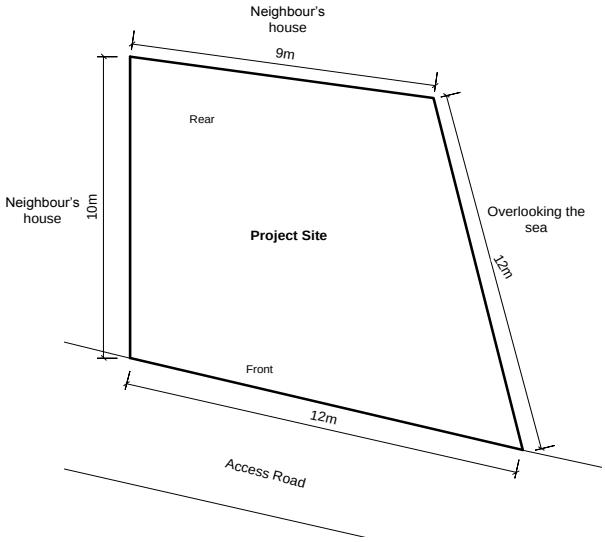
The assignment task with a simulated learning anchor was provided to students at the beginning of the session. The description of the learning anchor is as follows:

Scenario:

You work for a Design & Construct home builder in Sydney. Your company has recently received an invitation from a rich and famous sport-start (the client) who wants to build his dream house. The award of contract for this project will not be purely based on the lowest bid price; rather the client will look into a combination of factors such as the quality of design, cost, project plan, safety, sustainability, etc. In order to improve competitiveness and persuade the client visually, your company has decided to adopt BIM for the preparation of the bid package.

The house is to be built on a block of flat land near Darling Harbour. The dimensions and orientations of the project site are shown in the sketch below. The client requires at least the following features in his new house:

- *Number of storeys – 2*
- *Master bedroom with en-suite*
- *Additional bedrooms – 2*
- *Separate living & dining*
- *Modern kitchen*
- *Laundry*
- *Single garage*
- *Front yard and/or backyard*



Students were required to form groups of maximum five, play the role of the bid preparation team and prepare a bid package for the project using BIM. The submission required the following parts:

- A digital folder containing a summary report with all final details of the bid, a BIM model of the proposed house, cost estimates, project plans, 4D simulations, and other BIM analyses that form part of the bid package, and
- A 10-minute presentation to explain the bid details and persuade the client; all members of a group were required to present.

Detailed assessment criteria for the assignment were made available to students, allowing them to understand the standard of work expected.

Learning Scaffolding

Lectures and tutorials were structured to scaffold the progressive completion of the assignment task and thereby BIM learning. Lectures predominantly covered the core concepts of BIM and their various applications in construction while lab tutorials were designed to provide an environment for students to have hands-on experiences of applying classroom theories to solve such construction management issues as design management, cost estimating, project planning and risk management using BIM. Autodesk BIM software applications such as Revit, Navisworks, and QTO were used in the course.

BIMPedia

BIMPedia was developed for the course in order to support remote learning. BIMPedia featured video tutorials that explain various applications of BIM. It was placed on the Moodle eLearning platform but as an independent online learning support site. Figure 3 illustrates BIMPedia, with modelling roofs tutorial selected. Clicking on a given item on the list would open a video case example that elaborates on the BIM procedure for the task. Students could learn subjects related to BIM model creation, design coordination, 4D simulation and 5D BIM at their own time and pace with BIMPedia. There were twenty-four video tutorials related to these subjects and they were organised in a way that gradual learning is facilitated.

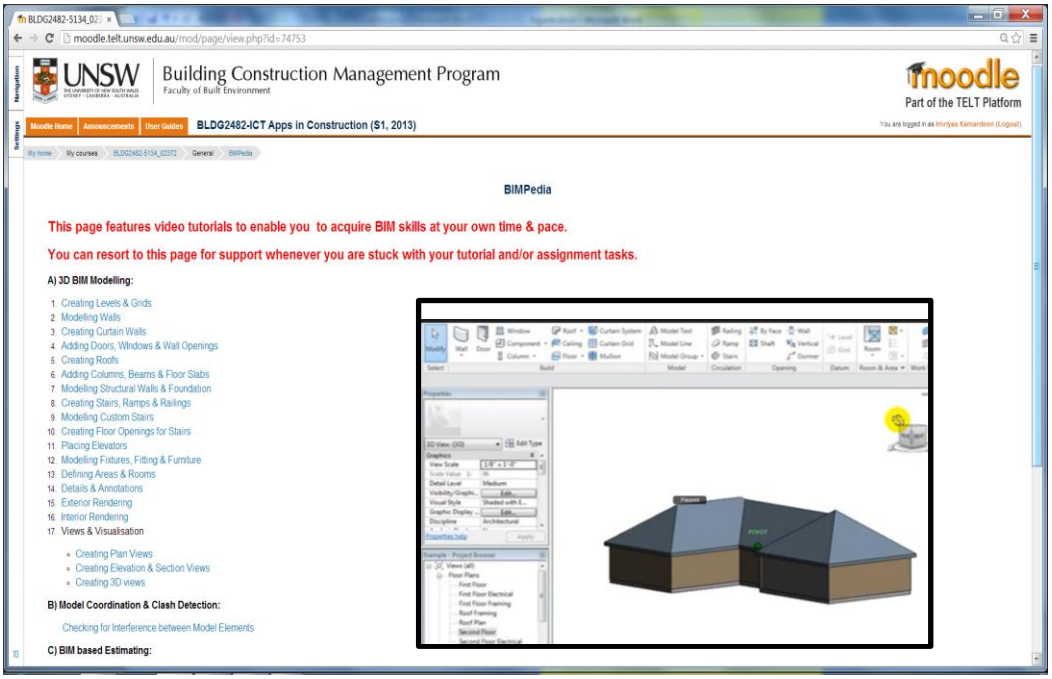


Figure 3: BIMPedia interface

STUDENT-DIRECTED LEARNING AND PERFORMANCE QUALITY

The prime aim of using the anchored pedagogical approach was to promote self-directed deep learning of BIM among students, as a way to nurture graduate attributes such as critical thinking, scholarly enquiry, teamwork and problem solving. The anchored learning task assisted in achieving the aim and the overall student performance was excellent. The account below explains how the students directed deep learning of BIM.

- On the first day when the assignment task was introduced, students formed groups and held discussions to make conceptual decisions for the proposed project. The lecturer was approached at the end of the exercise for feedback and for ensuring that their ideas were sound.
- Then, groups searched for information regarding local council regulations, building materials, sustainable construction methods, building cost, etc.
- With the knowledge and information gained thus far and the conceptual ideas, groups created BIM models for the project on Autodesk Revit 2013. During model development, group members constantly challenged each other's views on different and conflicting aspects of a design choice, before arriving a collective decision. The lecturer was approached when groups encountered serious technical or conceptual issues that they could not resolve themselves by self-study.
- The end product of that iterative process was a complete BIM model. There were ten different BIM models for the same project brief, representing different concepts and ideas of the ten groups.
- Upon developing the BIM models, groups moved on to generating a detailed cost estimate on Autodesk QTO. The passion for deriving an accurate cost estimate with adequate details drove students to refer to several cost guides and gather cost information from the local market.
- Parallel to cost estimating, groups prepared project schedules on MS Project for the construction of their models. Subsequently, groups prepared 4D simulations on Autodesk Navisworks. There were iterations in that groups optimised their project schedules in view of inefficiencies noted during 4D simulation plays.
- Most groups went beyond meeting the basic requirements for the submission. They undertook extra analyses such as sustainability analysis using Autodesk Ecotect, safety analysis using the 4D simulation and value analysis. It is noteworthy that techniques of carrying out these additional analyses were not covered by the author in the lectures or tutorials.
- The assignment task was completed in 12 weeks and most of the work was carried out outside the lecture and tutorial hours allocated for this course. Final class presentations that were made on the submission

date not only showcased groups' work but functioned as a means for learning by informal peer review and comparison/benchmarking.

The author's observations on the students' learning process witnessed the following key characteristics:

- All students were actively involved in the learning process
- Learning was largely driven by students and the lecturer provided only basic information or guidance
- Discussions and collaborations for problem solving within constraints were integral parts of their learning
- The task was perceived relevant to their work, which motivated students to acquire BIM skills seriously
- The task was felt challenging yet fun and enjoyable
- Scholarly enquiry and information seeking was a constant theme

An example of students' work is shown in Figure 4, which exhibits the depth of their analyses and quality of performance.

Figure 4: Student work, showing 3D BIM, 4D simulation & safety analysis

EFFECTIVENESS OF THE NEW PEDAGOGICAL APPROACH

A structured questionnaire survey was conducted to measure the effectiveness of the anchored instructional model for BIM education. The questionnaire consisted of three key sections. The first section gathered particulars of participants. The second section measured the effectiveness of the anchored instructional approach, with four subsections: organisation of the course, effectiveness of BIMPedia, effectiveness of the anchored learning task, and overall learning experience. Altogether there were twenty-six questions under these subsections. Participants' responses to these questions were collected on a 5-point Likert scale. The last section of the questionnaire received descriptive qualitative comments on two questions: what are the best features of the approach; and how may this approach be improved to further enhance learning experience. A paper-based questionnaire survey was conducted in the class and this approach was purposely chosen to improve the response rate. Forty-three out of 47students responded to the survey, making a response rate of 91%.

Survey Data Analysis and Discussions

Survey data was analysed to explore students' perceptions on the new pedagogical model for BIM education. Descriptive statistical measures of the quantitative responses for the questionnaire were computed as shown in Tables 1-4. Qualitative comments made by students were also analysed. The descriptive statistics in Table 1 suggest that the students had a very good learning experience in the course. They would like more of this kind of approach in other courses too.

Table 1: Student learning experience

Ref.	Survey question	Mean rating	Standard deviation
L1	Overall, how would you rate the effectiveness of the anchored learning assignment for developing your BIM competency?	4.1	0.7
L2	Overall, how would you rate the quality of teaching you received with the use of the anchored learning assignment in the course?	4.1	0.6
L3	Overall, how would you rate your learning experience/satisfaction in the course?	4.0	0.7
L4	How would you rate your preference to see authentic anchored learning assignments in other courses too?	4.2	0.7

It can be deduced from Table 2 that six attributes of the anchored instructional model contributed to very good learning experience of students, which were:

- Authentic nature of the learning task
- Active student engagement in the learning process
- Teamwork

- Richness of interactions and communications in the learning process
- Challenging yet interesting task
- Analytical and problem solving nature of the task

Table 2: Efficacy of anchored learning task

Ref.	Survey question	Mean rating	Standard deviation
A1	The anchored learning assignment was related to real-world practice (it fostered application- focused learning)	3.8	0.8
A2	The authentic style of this assignment was intellectually challenging and stimulating	4.0	0.7
A3	The assignment promoted active student engagement in learning activities	4.2	0.7
A4	The anchored assignment offered flexibility in learning style & choices	3.9	0.6
A5	The assignment was interesting and motivating me to learn	4.0	0.8
A6	The anchored assignment was effective for enhancing my critical thinking and analytical skills for problem solving	3.9	0.7
A7	The assignment was helpful for developing my skills of scholarly enquiry	3.8	0.9
A8	The assignment was effective for advancing my ability to engage in independent and reflective learning	3.9	0.7
A9	Working on this assignment helped me improve skills required for collaborative work/teamwork	4.1	0.8
A10	The assignment task helped in enhancing my skills to locate, evaluate and use relevant information for problem solving	4.0	0.7
A11	The assignment supported improving my communication skills (e.g. skills for presentation, articulation, discussion etc.)	4.1	0.7

Corresponding to this, three recurring themes were noticed in the qualitative comments made by the students to the question of "what are the best features of this approach to university learning", including: practical and relevant to real-world nature of the learning task, fostering active student engagement in learning, and interactions between students and the lecturer and among students. A large proportion (40%) of the qualitative comments appreciated the practical and relevant to real-world nature of the learning task. Some of the students' quotes related to this are as follows:

skills obtained from the course are transferrable to work

practical things to learn; more appropriate and applicable to the 'real world'

having more hands on learning is better to prepare students for the real world

engagement in this hands on approach to learning is essential to the retaining of learnt information and exploration of differing aspects of the material

engaged into the construction process; you allow the students to learn the actual construction process

Likewise, active engagement of students, both physically and mentally, as well as the richness of interactions together attracted 24% of positive comments. Some of the direct quotes of students are as follows:

independent learning allows for the development of curiosity and therefore a more student development centred approach

integrated learning, involve active students' participation

being able to work in a group and go through to full lifecycle of the assignment with an analytical approach

it lets you think critically and increase problem solving skills

interactive; teamwork

it is interactive and visual learning

Table 3: Structure of the course

Ref.	Survey question	Mean rating	Standard deviation
S1	The course contents were adequate to understand basic BIM concepts well	4.1	0.7
S2	The course was well organised & structured toward easy understanding of basic BIM concepts	4.0	0.8
S3	Each lesson was well linked with previous lessons to allow gradual enhancement of BIM knowledge & understanding	4.1	0.6
S4	Practical tutorials in the course reinforced my understand of basic BIM concepts	4.2	0.8
S5	The structure and organisation of lessons and tutorials well supported effective completion of the anchored learning assignment task	4.1	0.60
S6	Making clear assessment criteria available in advance helped me direct my learning better in the course	4.0	0.80

Table 4: Learning resources (BIMPedia)

Ref.	Survey question	Mean rating	Standard deviation
R1	The online library, BIMPedia, contained sufficient interactive video tutorials to support BIM learning	4.0	0.9
R2	Access to and use of BIMPedia for resolving learning issues was easy	4.0	0.9
R3	The interactive video tutorials contained in BIMPedia provided learning scaffolding for me	4.0	0.9
R4	BIMPedia offered improved flexibility in learning at my own time & pace	4.1	0.9
R5	BIMPedia was good support for effectively completing the anchored learning assignment in the course	4.0	0.9

Tables 3 and 4 prove that the organisation of the course and learning resources have been integral and supportive for the anchored learning. The qualitative comments made by student were analysed to recognise which aspects of the course organisation and resources were helpful for students. Four key attributes were noticed as significant to students, including:

- Gradual learning that enabled easy understanding of the subject
- Lab tutorials that allowed practical applications of concepts/theories
- Availability of online video resources for off-campus, flexible learning
- Helpfulness and support of the lecturer

Thirty six per cent of the qualitative comments made by students witnessed these and some of the relevant direct quotes of students are as follows:

It's gradual learning week by week, not overload and small, manageable tasks

Easy to learn

The labs and tutorials really allowed us to put the techniques that we learnt into action with help from lecturer available

In lab, teachers helped a lot, online learning materials

Tutorials provided us with important knowledge

The online videos made doing work at home easier as they clearly explained the step by step approach

Learning through the internet is very convenient

The lecturer was very helpful when being asked questioned

Although the overall learning experience of students was rated high, some questions in the questionnaire attracted mean ratings of less than 4.0 but more than or equal to 3.80. The qualitative comments for the question of "how may this approach be improved to further enhance student learning experience" were carefully analysed to recognise areas that can be potentially improved. The analysis found four aspects that may be improved, which were:

- Providing more specific details for the assignment task
- Providing more online resources and tutorials
- Making more tutors, labs and lab hours available
- Improved support for resolving technical issues with software

Direct quotes related to these are as follows as answers to the question, "how may this approach be improved to further enhance student learning experiences":

Clearer, more in depth requirements for work needs to be submitted

More vivid in anchored learning

More computer lab time

Having more BIM based tutorial exercises

Better tutorials online, designated for this class

More people available to help in the labs, only 3 people for so many students that need help make it difficult (a lot of waiting around)

Trouble shooting procedures --step by step methods of fixing little mistakes

CONCLUSION

Anchored instruction is an effective pedagogical model for developing in students the skills and attributes necessary for work. Different technological approaches may be adopted in implementing the anchored instruction depending on the nature and context of a given course. Regardless of the technological approach used, certain pedagogical qualities should embody the design and delivery of the course to attain the desired learning outcomes through the anchored instructional model. The anchored learning tasks developed should be:

- Authentic in nature and related to real-world practice
- Analytical and of problem solving nature
- Vivid in learning expectations
- Actively engaging students in the learning process
- Fostering teamwork, interactions and communications in the learning process
- Challenging yet interesting

The scaffolding lectures and tutorials provided by the lecturer should allow: gradual learning of the subject for easy understanding; practical application of concepts/theories; and flexible learning with adequate online resources. Moreover, the availability of help and support of the lecturer on-demand is crucial to make students' learning process as smooth as possible.

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