# Project-based learning and pedagogies for virtual reality-aided green building education: case study on a university course

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**Purpose**
Green building education, an important aspect of sustainability in higher education, has rapidly expanded across the world. Yet, a bespoke pedagogical model integrating the essential elements of green building knowledge into a university course is lacking. To plug this deficiency, the present study aims to develop an innovative pedagogical model that incorporates four types of teaching activities, viz., lecture, virtual reality (VR) aided site visit, physical site visit, and practicum-based project.

**Design/methodology/approach**
Based on an extensive review of the relevant literature and course materials, a pedagogical model was constructed for application to the teaching and learning activities of a university's hospitality and real estate programme. Using a case study approach involving in-depth interviews with green building professionals and a workshop coupled with an online survey on building professionals, the model's transformative effectiveness was evaluated.

**Findings**
The study finds that the pedagogical model was able to effectively equip students with the essential green building knowledge pertinent to the different stages of a building lifecycle. Concerns about wider applications of the model, including barriers to implementation in other academic programmes and resources for updating the VR platform, were identified.

**Originality/value**
The VR-aided and project-based pedagogy model is novel and effective in delivering green building education. Future work, particularly expanding the VR platform to cover more green building cases, thereby allowing multiple case studies to be conducted, is recommended for illustrating further contributions and implications of the model.

**Keywords:** green building education; project-based learning; virtual reality; pedagogical model; site visit.

## 1. Introduction

The sustainability agenda has been incorporated in a variety of business and operation practices (Lindsay et al., 2021). To attain the sustainability goal, green building education is an important

strategy (Cole et al., 2021). Some countries have started to integrate green building knowledge to different educational levels to reinforce their citizen awareness on environmental sustainability (Häkkinen and Belloni, 2011; He et al., 2018).

Spending most of their time indoors, people are closely attached to the built environment they occupy. In fact, the buildings and buildings construction sectors combined are responsible for the majority of energy consumption and nearly 40% of total direct and indirect $CO_2$ emissions (Lu and Lai, 2019; International Energy Agency, 2021). Human behaviour is significantly related to built environment performance, thereby affecting the lifespan of buildings. Increasing people's environmental awareness is, therefore, a prerequisite to understanding human impact on the built environment and the climate. It has been proven that green building knowledge can significantly raise the public's environmental awareness which helps regulate human behaviour such as energy saving or waste reduction choices in the built environment (Hou and Wu, 2021).

Recognising the role of green building in raising community's environmental awareness and relating to efforts in promoting green building development, the idea of integrating green building knowledge into higher education curricula has emerged. Courses in the disciplines such as engineering, architecture, urban planning, construction and real estate, which deliver structured knowledge about the built environment, are suitable to embrace green building knowledge. However, they usually focus on one aspect of the knowledge body. For example, courses in some engineering programmes focus on explaining the technical details of building design and practice, while urban planning courses elaborate more on issues about land use and ecology. A pedagogical model that integrates all essential aspects of green building knowledge into the curriculum design at higher education level remains to be seen.

To address the above deficiency, a project-based learning (PBL) pedagogical approach, which advocates designing learning activities to enhance student engagement and enables students to conduct constructive learning, is appropriate. Furthermore, virtual reality (VR) technologies were used to transform the technical aspects of green building knowledge in the form of a virtual site visit. Incorporating this virtual site visit, a physical visit and a series of lectures, a pedagogical model was developed for implementation in a university course from Hong Kong. To evaluate the model's effectiveness, this paper adopts a case study approach, in which two stages of data collection were organised to examine the model's implementation. Stage 1 involved interviewing nine green building specialists for their comments and reflection. Stage 2 involved arranging a workshop to further gather opinions from professionals in the green building industry.

The ensuing sections are as follows: sections 2 and 3 present a literature review on green building education and the PBL pedagogy integrated with VR technologies; section 4 recounts the development of the above-mentioned pedagogical model and explains the components of the model; section 5 reports the case study results. Finally, section 6 concludes this paper with suggestions for future works.

## 2. Green Building Education in Higher Education

To strengthen the public's environmental awareness and to enable sustainable building-human relationship, green building education serves as significant link between people's environmental awareness and built environment operation (Cole, 2013). Public infrastructures have been built 'green' to: first, reduce energy consumption and commit to sustainable built environment practice, and second, foster public's understanding of green buildings and their operation. For example, many academic institutions have developed their green buildings to

showcase knowledge about sustainability (Cole and Hamilton, 2020; Cole and Altenburger, 2019; Jones and Wong, 2016).

To foster the next generation of green architects who would promote sustainable development, architectural educators took the initiative to construct curriculum that is interwoven with understanding of green building. Important elements of green buildings are covered in the courses related to green buildings in the context of architectural education around the world, including interdisciplinary knowledge (particularly collaboration with engineers to optimise design schemes), active and passive design strategies, building performance simulation, and green materials (Xie et al., 2020). Although educators in the architecture discipline make every effort to create a cutting-edge green building education curriculum, there is a lack of a unified and targeted curriculum framework to draw students' attention to environmental sustainability issues associated with green buildings and to motivate students to learn the skills and knowledge in an active approach (Ismail et al., 2017; Xie et al., 2020). Oktay (2019) also suggests that it is equally crucial for the design to meet the built environment users' physical, social, emotional and spiritual needs as well as to ensure local distinctiveness together with a sense of place.

Aside from architectural education, green building education has also been incorporated in a number of higher education curriculums in the past decade, for example civil engineering (Kevern, 2011), interior design (Pektaş et al., 2015) and product design (Cole, 2019). Sustainability courses have been established in business school curriculums (Üçok Hughes et al., 2018); they focus on educating business students to pursue economic, environmental and social justice and equity in business activities (Landrum and Ohsowski, 2017).

In view of the lack a systematic framework for integrating green building education into the study of everyday environments, Cole (2019) developed a green building literacy framework, which contains three dimensions: "green building knowledge and skills", "affective dispositions and green buildings", and "behaviours and green buildings". The "green building knowledge and skills" dimension, covering an array of green building facets (viz. sustainable sites, location and transportation, shape of building, energy and atmosphere, water, material and waste management, indoor environment quality, social justice, beauty and inspiration, economics, life cycle assessment, operations and metrics, local and healthy food, and policy) comprises two knowledge categories: factual and procedural, both of which being essential for green building education. This literacy framework defines the components of green building education in all of its educational stages.

## 3. Project-based Learning and VR Technologies Integration

Project-based learning (PBL) represents student-centred pedagogy that encourages knowledge construction through actively engaging, solving and completing practical projects (Guo et al., 2020). It is effective in actively engaging students in a learning process that simulates practical professional scenarios (Bas, 2011). In the past two decades, the focus of education studies has shifted from teaching-oriented to student-centred. As a new paradigm in higher education, student-centred pedagogies have received unprecedented attention.

What distinguishes PBL from other student-centred pedagogies is its inquiry-based teaching and learning focusing on creating tangible artifacts for problem solving (Krajcik and Shin, 2014; Guo et al., 2020). The process expects learners to work together to develop solutions for authentic problems in the process of knowledge integration, application, and construction. Instructors and community members (e.g. clients), normally as facilitators, provide feedback and support for learners to assist their learning process. This constructivist approach allows

students to develop their understanding and form knowledge system by themselves through the completion of multiple learning tasks (Liu et al., 2010). Through PBL participation activities, students are to develop capacity in critical thinking, creativity, leadership and communication skills (Kubiatko and Vaculová, 2011; Luo and Wu, 2015).

Due to its six unique features (viz. engaging students in real-world tasks, student-centred small work, simulated professional situation, processing multiple information sources, teacher as facilitator for learning and resource guide, and formulative and performance-based evaluation (Brundiers and Wiek, 2013)), PBL has been increasingly used in engineering and construction management education settings with integration of technologies as a supporting tool (Frank et al., 2003; Goedert, et al., 2013; Gratchev and Jeng, 2018; Chua and Islam, 2021). Engineering and construction professionals are highly involved in project-based practices. Although the majority of them participate in projects focusing on certain stage(s) of project life cycle, their knowledge of project life cycle affects their decision and level of fineness in completing tasks. In response to industry needs, university engineering and construction programmes incorporate PBL in their curriculum design and delivery (Leite, 2016).

Digital technologies, which have been increasingly incorporated in PBL (Lepe and Jiménez Rodrigo, 2014), are used to create virtual environment for online teaching (Ravitz and Blazevski, 2014). VR technology has gained high level of popularity which has been driving innovation in many disciplines to support teaching and learning activities (Sanchez et al., 2000). One main application of VR technology in higher education is to create virtual learning environment to simulate or represent the practical environment where learners have cognitive experience to develop their knowledge systems through interaction with the knowledge that is presented in the virtual world (Fowler, 2015; Sanchez et al., 2000).

Although the pedagogical role of VR technology is yet to be fully revealed, some studies found that it contributes important pedagogical value in education. Bloom's taxonomy of learning suggests that VR educational application is more efficient in facilitating cognitive learning instead of procedural and affective learning (Bloom et al., 1956; Fowler, 2015). Johnston et al., (2018) identified the pedagogical foundations of existing VR educational applications, namely, direct instruction, experiential learning, discovery learning, situated cognition and constructivism. They also stated that these pedagogical approaches provide good implication to educators and VR designers for developing compatible VR education products to facilitate student learning activities. A recent systematic literature review (Hamilton et al., 2021) shows that the majority of studies of VR educational applications concentrate on the cognitive domain and 24% of the studies relate to engineering and architecture education. VR technologies as a pedagogical tool in course design for built environment education is inevitable.

VR technologies and PBL appear to complement each other in supporting constructive learning (Halabi, 2020; Tseng, 2020). VR technologies are utilised to simulate real-world scenarios to allow teaching-learning occur in an active and constructive process. The PBL approach enables learners to appreciate the purpose of VR technology and its applications.

## 4. Development of a VR-aided four-quadrant pedagogical model

In alignment with Cole's (2019) green building literacy framework, a VR-aided four-quadrant pedagogical model was developed to support the curriculum design this study investigated. The four quadrants are structured based on the PBL approach, starting with a number of fixed units of traditional lecture-based teaching for knowledge delivery. This is followed by two site visits: one simulates the real green building environment for students to experience and observe on an individual basis; the other illustrates green practice of building professionals. The course ends with students' presentation of their group-based project.

Figure 1 illustrates the design of the model. The four quadrants are arranged based on four spectrums: i) cognitivism plus individual learning, ii) constructivism plus individual learning, iii) cognitivism plus problem-solving and teamwork, and iv) constructivism plus individual learning plus problem-solving and teamwork. Cognitivism and constructivism are two basic learning theories. Cognitivism puts human cognition at the centre, arguing learners' intellectual development follows the knowledge acquirement process which involves receiving, storing and retrieving information. It believes that learners acquire knowledge on an ascending spiral basis (Shuell, 1986). Constructivism argues that learning process is driven by the learners where knowledge acquirement process represents "knowledge construction" process, in which the learners actively build subjective representation of the newly learned (Fosnot, 2013). Comparing to cognitivism, constructivism argues that learners play a navigating role and prefer learning from experiencing (or 'learning by doing').

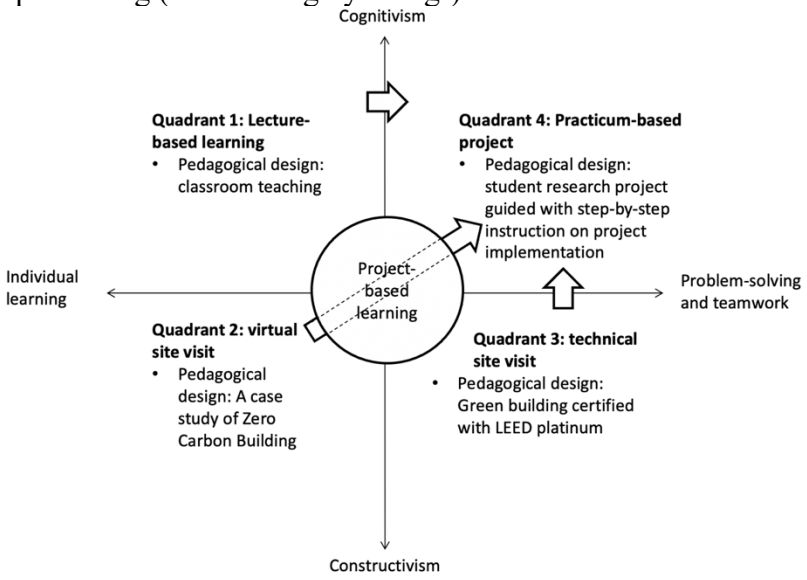


**Figure 1.** VR-aided four-quadrant pedagogical model

Quadrants 1 to 3 (Figure 1) are designed to facilitate students to complete the student-based research project by providing factual and procedural green building knowledge (Cole, 2019). In the first quadrant, the instructor mainly conducts classroom teaching to enforce knowledge delivery. In the second and third quadrants, two experience-based site visits are organised to highlight the constructivist approach. Furthermore, the PBL approach emphasises teamwork (Mujika et al., 2013), which is regarded as one of the problem-solving techniques and a real-world practical model. Thus, a group-based research project is designed to enable students to experience teamwork activities and work on teamwork spirit development.

In order to create opportunities for learners to acquire knowledge on an individual basis, a virtual site visit was designed and incorporated. The VR materials were developed based on the ZCB. Through the virtual site visit, students are exposed to the green building features, such as recycling bin, gabion wall, eco paper, micro-climate monitoring station, high-volume-low-speed ceiling fan, chilled beam, under-floor air supply, and water-efficient fixtures (ZCB, 2021). A technical site visit to a green building is organised to allow students engage in practical context of the built environment and directly interact/communicate with building professionals.

In quadrant 4, students deliver group-based presentations and reports. The practicum-based project requires students to complete using the knowledge learned in the preceding sessions, including lectures, virtual site visit and technical site visit. During the four-quadrant process,

the instructor provides instruction to guide students through their learning process and their acquisition, review and reinforcement of the new knowledge.

## 5. Case Study

A case study was conducted  investigate the transformation and effectiveness of the proposed pedagogical model into teaching and learning of a course of hospitality and real estate programme. In the following, the case study context, the development of VR platform for the virtual site visit, the implementation of the course and the interviews are explained.

### 5.1 Case study context

The course on which the case study was conducted is part of a hospitality and real estate (HRE) programme in one of the universities in Hong Kong. The HRE programme is designed to develop professionals for both the hospitality and real estate industries. As the two industries have become more connected through property planning and development, business operations, marketing and customer relationship, technologies and many other ties, the programme offers various courses that combine elements from both hospitality and real estate fields.

A mandatory course open to final year (Year 4) students in the HRE programme, the name of the course was “facilities development and management for hospitality and real estate industries”. The objectives of the course include: 1) to deliver knowledge of the planning, design, construction and operation of hospitality real estate development; 2) to enable students to master professional skills in conducting market research, monitoring the planning and development process, and operation management; and 3) to foster students to develop critical thinking and problem-solving skills. Attaining these objectives entail real estate development knowledge, critical thinking capability and problem-solving skills, and these three components need to be strengthened through teaching and learning activities specifically designed for the course. To this end, the proposed VR-aided four-quadrant pedagogical model was applied.

Recognising the hospitality and real estate industry has committed to sustainability practices such as reducing waste, improving energy efficiency and adopting environmentally friendly materials (Hou and Wu, 2021), knowledge of sustainability and environmental management needs to be integrated in hospitality and real estate curriculum. According to Cole (2019)’s green building literacy framework, green building education is suitable to be integrated in a hospitality real estate programme. It emphasizes not only the concept and factual information on green building, but also how to engage green practice in building operation. For students from a hospitality real estate programme, green building knowledge can facilitate both building knowledge and green operation management principles. Moreover, considering that real estate development knowledge plays a crucial part in a hospitality real estate course, the knowledge delivery strategy is designed based on building life cycle stages, namely, conceptual development, feasibility studies, planning and financing, construction and project management, and operation and post-occupancy management. Green building knowledge is categorised based on the five-stage real estate development life cycle to be integrated in the course design.

In addition, PBL is often adopted in hospitality curriculum as practical experience is critical for nurturing hospitality professionals. In a hospitality programme, practicum is a mandatory course for every hospitality student. Students are required to conduct internship at a hospitality organisation for a certain period of time in order to complete the mandatory course credits for the practicum.  students need to submit a report to reflect their internship experience and human resource managers from the internship hotels are involved in evaluating students’ performance during their internship. Internship is typical PBL course in hospitality curriculum.

### 5.2 Development of the VR platform to support virtual site visit

The VR platform was developed in the form of a virtual video. It enables students conduct site visit in continuous virtual environment. It is composed by a series of 360-degree photos taken by the instructor at the site of the ZCB. The photo-editing was supported by a professional VR company. The instructor was responsible for writing scripts, designing path of the virtual site visit and recording the voice-over for the video narration.

The virtual site visit allows students to self-navigate at a digitally representation of an actual place. Green building knowledge is embedded in the video in the form of texts or images, and the learner can access the knowledge by "selecting" the "virtual buttons" in the virtual environment. Students can choose to view either the 2D or 3D version of the VR video and VR glasses were provided in the classroom for students to conduct 3D virtual site visits. The functions of the VR platform are illustrated in Figure 2.


**Figure 2.** Functions of the VR platform

### 5.3. Implementing the course based on the pedagogical model

Based on the pedagogical model, Figure 3 shows an overview of the implementation process of the course. Figure 4 illustrates the specific teaching and learning activities designed based on the pedagogical model. The course is then divided into four quadrants: lecture-based teaching, virtual site visit, technical site visit and practicum-based project.

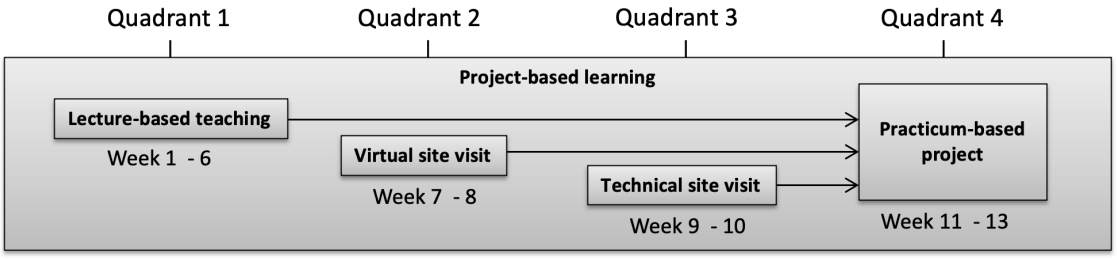


**Figure 3.** Implementation process of the course

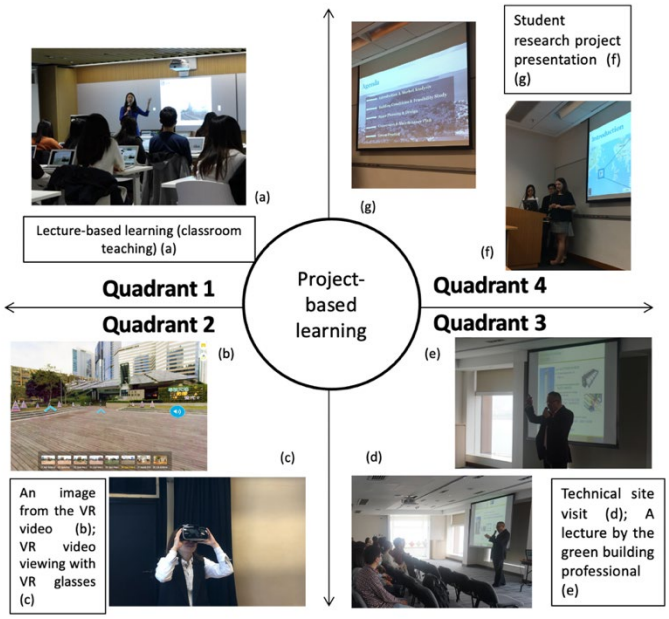


**Figure 4.** Teaching and learning activities implementation

### 5.3.1 Quadrant 1 – lecture-based teaching

The course consists of 13 sessions in total (one session per week) and each session is 2.5 hours. The first six sessions were delivered in traditional lecture-based teaching mode. In the first lecture, the instructor provided a course overview and detailed instructions of the practicum-based project. Students were randomly arranged into different groups, with a maximum of six students per group.

From week 2 to week 6, lectures were delivered based on five topics that reflect hospitality real estate development, namely (1) concept development, (2) feasibility studies, (3) planning and financing, (4) construction and project management, and (5) operation and post-occupancy management (Figure 4(a)). These lectures focus on knowledge about developing and managing hospitality real estate, with extensive elaboration on green hospitality real estate (e.g. green hotel, green museum). Table 1 indicates the contents included in each lecture and the green building knowledge covered in each lecture.

**Table 1.** Integration of green building knowledge into the lecture contents

| Lecture week | Development stage | Hospitality real estate | Green building knowledge |
|---|---|---|---|
| Week 1 | Course overview / detailed instructions of the practicum-based project | | |
| Week 2 | Concept development | ○ Forming development concept | ○ Concept of green building<br>○ Green building rating and certification systems<br>○ Benefit of green building |
| Week 3 | Feasibility studies | ○ Market analysis;<br>○ Site assessment;<br>○ Environmental impact assessment;<br>○ Development pro forma;<br>○ Establish development teams | ○ Cost-benefit analysis for green building development<br>○ Sustainable site<br>○ Land use and ecology<br>○ Transportation<br>○ Liveable community<br>○ Corporate social responsibility |
| Week 4 | Planning and financing | ○ Marketing strategy implementation<br>○ Drawing development: architectural/mechanical<br>○ Detailed financial plans | ○ Green design: active design and passive design<br>○ Green building systems:<br>◊ Energy design<br>◊ Envelope design |

| | | | |
|---|---|---|---|
| | | development<br>○ Secure necessary government regulatory action | ◊ Ventilation design<br>◊ Water system design<br>◊ Light design<br>◊ Mechanical design |
| Week 5 | Construction and project management | ○ Schedule development and management;<br>○ Tendering and procurement management; | ○ Green procurement<br>○ Green project management<br>○ Construction material waste management<br>○ Environmental management |
| Week 6 | Operation and post-occupancy management | ○ Facilities management;<br>○ Maintenance management;<br>○ Lease/sales;<br>○ Grand opening | ○ Water management<br>○ Energy management<br>○ Indoor air quality management<br>○ Green human resource management<br>○ Sustainable practice in hotel management |

### 5.3.2 Quadrant 2 - virtual site visit

15 pairs of VR glasses were prepared for the course. The participating students were divided into two batches for attending the virtual site visits in week 7 and 8 respectively. A QR code was provided and the students accessed the VR video by scanning the QR code with their smart phones. The video supports both 2D and 3D versions for viewing. Students can view the 2D version using a computer/laptop, and the 3D version with the support of VR glasses and smart phones. Figure 4(b) is an image cropped from the VR video and Figure 4(c) is a picture showing a student viewing the 3D version of the video.

The VR platform allows students explore the site in the virtual environment at their own pace. Students can control their viewing pace by clicking the "blue arrows" in the VR video and they can receive voice-over narration through clicking the "blue audio icon". Figure 4(b) shows two arrows and an audio icon. The arrows lead students to the next destinations at different locations of the ZCB. When selecting the audio button, students can listen to the narration embedded in the VR video to learn the background information about the ZCB and elaboration of the green building features (Figure 4(c)).

### 5.3.3 Quadrant 3 - technical site visit

The week 9 lecture involved a technical site visit at a green hotel (Figure 4(d)). The hotel is a green building with a number of accreditations from international green building associations, such as LEED-NC Platinum of the U.S. Green Building Council, BEAM-plus of the Hong Kong Green Building Council, and Green Mark's Provisional Platinum of Green Mark Singapore. The building itself provides pedagogical values, as it is a demonstration of state-of-the-art green building knowledge over its development life cycle.

The technical site visit was guided by general manager of the hotel, who gave an on-site guest lecture (Figure 4 (e, f)). This allowed the students hands on opportunity to witness the main design features and the green practice of the hotel. The students also had the opportunity to interact with the general manager and learn from him green hotel management knowledge.

### 5.3.4 Quadrant 4 - student practicum-based project presentation

A reflection session, in week 11, summarised the teaching-learning activities in the preceding 10 weeks. Students were given detailed feedbacks and instructions regarding their reports. In weeks 12 and 13, each group of the students presented their project report (Figure 4(f)&(g)).

The project served as the major student assessment of the course. Students were required to utilize the knowledge learned in the course to produce a green real estate development project report. The detailed requirements of the project include:

- Clearly indicating the concept of the green real estate development project;
- Conducting market research with both first-hand and second-hand data to justify the business concept and design concept (interviews with hotel professionals and survey with hotel users are required);
- Reporting the results of the financial and physical feasibility studies;
- Delivering an architectural design layout and functional design layout of the green real estate; and
- Developing marketing strategies and a management plan for the building operation after the grand opening.

### 5.4 Interviews with green building professionals

Effectiveness of PBL is usually measured through affective outcomes (i.e. perceptions of the benefits of PBL and perceptions of experience of PBL) or cognitive outcomes (i.e. knowledge and cognitive strategies) (Guo et al., 2020). To determine whether the VR-aided four-quadrant pedagogical model is suitable for application in the course under study, an evaluation of learning objectives and course delivery context is necessary (Hou and Wu, 2020). External review and feedback were solicited for course design/delivery quality assurance purposes. Professionals working in the green building industry, hereinafter referred to as "green building professionals", were invited to provide their review and feedback through interviews [with human subject ethics application review approval (No. HSEARS20220227001) from the project leader's university].

#### 5.4.1 Sampling and interviewee profiles

A purposive sampling (Bloor and Wood, 2006) was made to select the interviewees to match with the objectives of this study. The interviewees were selected based on their experience in design/management/evaluation of green buildings or in teaching green building knowledge. Interviews with nine green building professionals (interviewees A to I) were conducted to collect their opinions on: 1) green building education in the context of higher education in Hong Kong, 2) pedagogical model design and implementation, and 3) the course design based on the pedagogical model and the course implementation.

The job titles and organisation backgrounds of the nine green building professionals are shown in Table 2. The professionals had work experience in different stages of green building development. Interviewees A, B and D were involved in green building management while interviewee C was responsible for green building design and development. Interviewee E was a professional green building scheme accreditor. Interviewee A was a general manager of a hotel in Hong Kong and this hotel is accredited as a green building by a number of green associations. Interviewee A were also involved in teaching how to manage green hotel in some hospitality related programmes in Hong Kong. Interviewee B worked for a four-star hotel in Hong Kong and was the Director of Engineering of the hotel. This hotel was involved in undergraduate internship programmes with a university in Hong Kong and, from time to time, this interviewee invited to give guest lectures for that programme. Interviewee C was an architect for a signature green building in Hong Kong and he engaged himself in promoting green building by giving lectures at education institutions of different levels. Interviewee D was a facilities manager of a green building and she was also an instructor, teaching facilities management related subjects in Hong Kong. Interviewee E, an authorised accreditor of BEAM Plus, was a researcher working in a university. Interviewee F was working in a real estate consulting firm. In his position as a real estate consultant, interviewee F was in charge of offering sustainable built environment solutions. Interviewees H and I are two university professors whose research interests lie in green building labelling/certification and green environment policy development respectively.

**Table 2.** Profiles of the interviewed green building professionals

| Interviewee | Job title | Organisation |
|---|---|---|
| A | General manager | Hotel[1] |
| B | Engineering department director | Hotel[1] |
| C | Architect, LEED AP | Architectural firm |
| D | Facilities Manager of a green building | Real estate developer |
| E | Green Building Accreditation Scheme Accreditor | Researcher |
| F | Real estate analyst (specialised in green building development) | Consulting firm |
| G | Assistant manager | Bank |
| H | Professor of urban studies | Higher education |
| I | Professor of urban planning and environmental science | Higher education |

[1] Green hotel

Interviewees A, B and C were familiar with the hospitality real estate course before the interviews as they were invited to teach a guest lecture before. Comparatively, Interviewees D and E had less knowledge on the hospitality real estate course. Interviewees F and G were two program graduates who attended the program a few years ago, but they were not engaged in how the pedagogical model was used to conduct the course.

### 5.4.2 Interview questions

In order to understand application of the pedagogical model and its effectiveness in promoting green building knowledge, three open-ended interview questions were used. Each interview started with an introduction of background of the programme, course structure and pedagogical model, followed by the three open-ended questions:

- Can you share your understanding of the current status of green building education in the context of higher education institutions in Hong Kong?
- As I have explained to you the four-quadrant pedagogical model and implementation in a specific course, what do you think of the pedagogical model and its effectiveness in facilitating green building education?
- What do you think of the design and delivery process of the hospitality real estate course?

### 5.4.3 A workshop

A workshop was organised to obtain feedback on the pedagogical model from a larger group of building experts after the in-depth interviews were completed. Forty-five building professionals from a variety of backgrounds were invited to participate in the online workshop. Participants in the workshop included building service engineers, managers of property management companies, project managers, and architects, among others. They all had more than three years of work experience in Hong Kong's green building industry and they were part-time students of a university's building-related master programme in Hong Kong. They did not take the hospitality real estate course implemented based on the pedagogical model, thus they were unaware of the course details prior to taking part in the workshop. The workshop was arranged in three parts. In the first part, the first author gave an introduction of the pedagogical model and its implementation process. In the second part, the Zero Carbon Building VR platform was demonstrated to the workshop participants; after that, the workshop participants were invited to complete an online survey composing four questions. The four questions were created to better understand the workshop participants' perspectives on green building education in Hong Kong as a whole, their insights on whether the pedagogical model would facilitate green building education, their perceptions of the integration of VR technology in specific course context, and whether they would be willing to enrol in a course supported by

the pedagogical model. The first two questions are the same questions used in the in-depth interviews. The third and fourth questions, as listed below, were derived from the third question used in the preceding in-depth interviews because the workshop attendees might not know the details of the hospitality real estate course:

- What are your opinions on applying VR technology in delivering the hospitality and real estate course?
- If you are given the chance, would you like to attend a green building related course designed based on the pedagogical model?

Messages and patterns of the online survey responses were examined using content analysis. The qualitative data was transcribed into texts and examined in detail by the researcher. The main interview responses fell in three main categories: (i) contribution, and (ii) barriers and (iii) recommendation, as analysed below.

### 5.4.4 Interview results

#### 5.4.4.1 Contribution

Responses in the "contribution" category are the comments given by the interviewees on the strengths of the pedagogical model in facilitating green building knowledge at higher education level and industry levels.

***Innovative pedagogy in promoting green building knowledge***

The four-quadrant pedagogical model was commonly regarded as an innovative pedagogy in promoting green building knowledge. All interviewees acknowledged that the pedagogical model acted as a "tool" in guiding the instructor to "weave" green building knowledge into the existing academic programme. The four-quadrant design of the pedagogical model integrate both textbook knowledge and practical experience in a course and it can progressively lead students to utilize and reflect textbook knowledge in practical activities. The innovation lies in three aspects: first, the attempt to integrate green building knowledge into the existing curriculum is innovative; second, the VR platform is an innovative element that helps to raise students' interest in green building knowledge and provides an alternative learning method to allow students to learn in a flexible way; third, the project-based pedagogical design helps students to reinforce the knowledge learned and develop problem-solving and teamwork skillsets.

After viewing the pedagogical model, the interviewees were impressed by the structured design of the pedagogical model in the course design and delivery. Their main comments included: "each quadrant has a specific focus, which allows students an easy overview of the course"; "The contents were designed structurally, following the development stages in a building life cycle"; "The model is a good way to show how the green building concept is accomplished in the real world"; "The proposed pedagogical model have prospects in offering first-hand knowledge in green building design and management in real life". In addition, the interviewees showed interests in the VR platform, especially implementation of virtual site visit. They believed that virtual site visit can boost students' interests in green building. Interviewee H mentioned that "The blending of virtual and physical site visits is more conducive to the development of professional competence for the future building/real estate professional in several ways".

What is worth noting is that interviewees rated highly the project-based pedagogical approach. They believed the final project drove students to proactively pursue knowledge and facilitated their developing problem-solving capabilities. Interviewee A opined that students in hospitality

and real estate programme should equip hands-on skills to support them to cope with tasks at both operational and managerial levels in their future career; a final project that requires building life-cycle knowledge would help students to understand built environment-human-relationship and the principles of organising business activities in certain built environment-human scenarios. Interviewee B also considered that the PBL approach is a solution to systematically integrate the knowledge from each lecture into a project-based task; this approach facilitates students to complete the tasks by taking into account a broader picture including the whole life cycle of a building; and the PBL approach is a good way to unleash students' potential in management activities in the future. Interviewees C, D and E provided positive comments. They suggested the PBL approach helps simulate real-world practice where students apply the theoretical knowledge to practical project work.

Furthermore, the interviewees highly acknowledged the effectiveness of the PBL approach in weaving different pedagogical activities together to become a package that enable the students to reflect on various "cohorts" of knowledge and apply them effectively in project. Interviewee C shared that it is necessary to enrich students not only with up-to-date real-world knowledge but also real-world practices. This is, essentially, project-based collaboration.

***Beneficial to the industry practice***

All of the nine interviewees believed that green building knowledge shall be effectively delivered to future professionals who will closely work in the built environment sector. They considered that the pedagogical model contributes not only at the education programme level, but also at the industry level. Interviewees A and B revealed that many university graduates from hospitality programmes are not familiar with building components, not to mention knowledge on energy saving and green building design. Interviewee A also suggested that the built environment, especially hotel rooms, is part of the "service" delivered to hotel guests; thus, all hoteliers shall develop a better understanding of the hotel buildings and a sustainable way to manage them. Interviewee B revealed that aside from managing engineering facilities of hotel buildings, he is also responsible for corporate social responsibilities (CSR) practice such as recycling, beach cleaning and food donation. He argued green building management is an important part of a hotel's CSR practice and therefore, young hotel professionals should be taught both "hard" and "soft" sustainability practices. By "hard" practice, he referred to green building knowledge. By "soft" practice, he meant the knowledge of the green building accreditation scheme and processes, corporate social responsibilities, etc. Interviewees C and D regarded hotels as commercial real estate and hotel operation management as highly similar to office or retail building operation management. Interviewee C showed a high level of support in teaching green building knowledge to students in a real estate programme because he has been actively promoting green building education to the general public. Interviewee H indicated that "the use of disruptive technologies in teaching and learning allows the students to understand the applications of disruptive technologies and inspire them (students) to incorporate the technologies in their future professional practice".

In summary, the interviewees highly praised the application of the pedagogical model in hospitality real estate programmes. Supported by the pedagogical model, the course helps to fill the important knowledge gap and supplement the green building knowledge for students, according to the interviewees.

#### 5.4.4.2 Barriers

In regard to existing and future barriers, the interview responses were mainly concerned with the future applications of the pedagogical model and the further utilisation of the VR platform.

***Barriers to future application of the pedagogical model***

Interviewees C, D and E raised that the PBL pedagogical model may not be widely accepted and adopted. First, lecture-based teaching is the most common approach in higher education in Hong Kong. Activity or project-based curriculum design only exists in limited cases. To design and implement the proposed four-quadrant pedagogical model would demand extra resources and time from the instructor's perspective. In terms of resource input, it may be costly for some education programmes to develop a tailor-made VR platform for promoting green building education in their field of study. Second, integrating green building knowledge into existing education programmes is a good initiative, but students with particular academic backgrounds may not be equipped with sufficient knowledge to understand green buildings. For example, students from an arts background may have little knowledge about the built environment. They may not know or be uninterested in the contents of the course. Third, while hospitality and real estate programme is suitable for green building knowledge integration as students from this programme are required to understand built environment knowledge, how to integrate green building knowledge into existing courses is major challenge. A first step is to identify common learning objectives of green building education and existing courses/programmes.

***Barriers to the further utilisation of the VR platform***

Interviewee D indicated that although the VR platform was well developed, it will need to be regularly updated. Even though the state-of-the-art green building knowledge is available from the VR platform, new technologies are applied green buildings so it is necessary to incorporate green building technologies in the VR platform. Interviewee C suggested that other green building cases should be added to the existing platform. The VR platform can include more than one green building case. Also, overseas green building cases can be demonstrated through the VR platform. This would allow students to remotely "visit" green buildings located in other countries. Demonstrating a local green building may seem not highly attractive to local students as they can readily visit the building physically.

#### 5.4.4.3 Recommendation

For "recommendation", the interviewees suggested establishing an elective general education course for students with different academic backgrounds to enrol. As green building knowledge may not fit in the learning objectives of all education programmes, it may not be suitable to integrate green building knowledge with the contents of education programmes unrelated to the realm of green buildings. Interviewees C and D suggested that green building education can be delivered in the general education section as an elective course so that students with various academic backgrounds are allowed to pursue green building knowledge. They pointed out that universities should create more channels for students to get in touch with green building knowledge. Both shared one type of green practice in Hong Kong: some secondary schools had refurbished their teaching facilities and buildings, and had them certified by the BEAM Plus of Hong Kong. They believe "having green building or refurbishment projects within education institutions" is one effective form of green building education initiative.

### 5.4.5 Survey results from the workshop

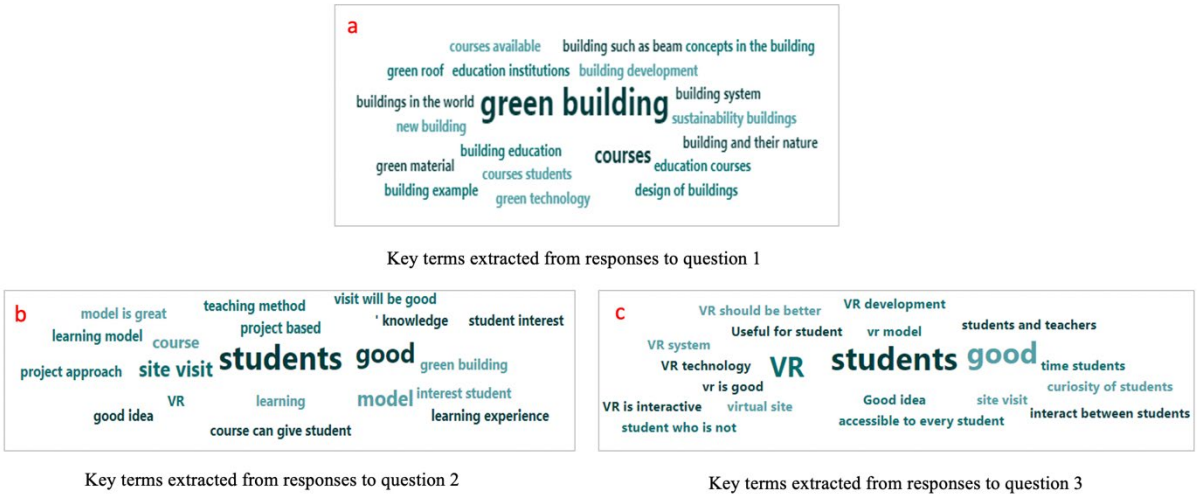


**Figure 5**. Keywords extracted from the survey responses

Three word clouds derived from the responses to survey questions 1, 2, and 3 are shown in Figures 5a, 5b, and 5c. The word clouds display the phrases or terms that the workshop participants used most frequently to answer each question. The major terms in Figure 5a can be separated into two groups: terms connected to education and terms that refer to green/sustainable building aspects such as green building, building system, green material, green roof, and green technology (e.g. education courses, building education, building example, education institution, course development). Participants in the poll provided thorough descriptions of how they understood green building education. The answers to question 1 did not contain any subjective statement.

The key terms extracted from responses to question 2 include students, site visit, model, learning experience, VR, learning model, teaching model, project based, student interest, etc. (Figure 5b). Some subjective statements were found in the responses to question 2, such as "Different from the traditional learning experience, it is a good idea to add different kinds of elements into the learning (activities). It can increase students' interest and draw their attention on the course in an easier way"; "In my view, it is more effective method to learn knowledge, it is because we can learn both basic knowledge as well as having unique experience of learning", and "…this is a good flow to help student who know nothing and have some take-away after completing the course. The project-based course can allow students to absorb the practical experience after the project completion".

Figure 5c shows the key terms extracted from responses to question 3, which are about the workshop participants' opinions regarding VR application in the hospitality and real estate course. "VR" is the term that frequently appeared among the responses and they are all associated with positive statements, such as "It's new and fresh. I never tried and would like to try this", "I think the VR model is very well established now. For students, it should be easy to learn", "It makes learning livelier and more interesting", "Virtual reality (technology) can improve education by providing students with memorable and immersive experiences that would otherwise not be possible. What's more, it can all take place within the classroom or at home. VR is accessible to every student and can be easily monitored by teachers. Virtual experiences have the power to engage and inspire students in a unique and powerful way", and "…It is also a good environment that student should take a basic feeling to walk around in virtual environment, and if they find some interesting in the virtual environment, they are allowed to focus on detailed elements". The overall responses showed that building

professionals are very fond of the disruption of VR technologies and regard it as effective in facilitating students' learning experience.

According to Figure 6, over 80% of the workshop participants showed their intention to attend a course designed based on the pedagogical model. Only a tiny proportion (2%) of the participants showed strong disagreement in their intention to attend a green building related course designed based on the pedagogical model.

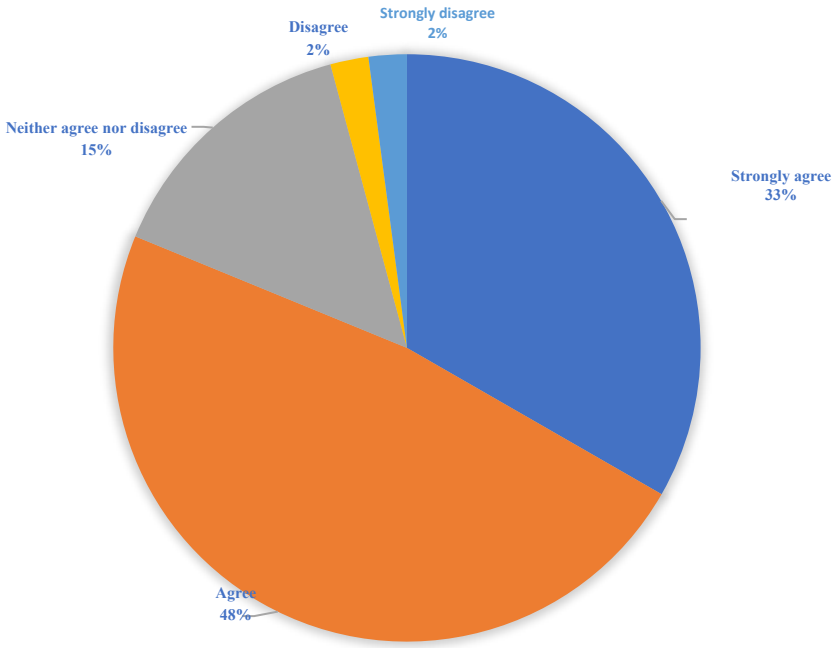


**Figure 6**. Workshop participants' intention to attend a green building related course designed based on the pedagogical model

## 6. Discussion

Based on the above results, three aspects of discussion are elaborated in the following.

### 6.1 Pedagogical implication of PBL on green building education

The course structure was developed based on a VR-aided four-quadrant pedagogical model, which aims to create dynamic learning to raise students' interests and facilitate their learning. The PBL approach was used to create cohesive course design, strengthen the logical connection among the lectures and enable students to develop critical thinking in a constructivist learning paradigm. The lecture-based teaching and site visit activities were combined to reinforce the interactions between knowledge (or theory) and practice. The student project served as an "umbrella" to embrace the course contents and learning activities in a cohesive way. It helps reflect course structure, build a solid link between course contents and assessment criteria, and integrate innovative learning into the curriculum.

However, there are challenges amidst the process of integration of two systems of knowledge bodies. The integration comprises three dimensions: incorporate appropriate green building knowledge into the curriculum, fuse lecture-based learning with activity-based learning, and integrate factual (engineering, architecture related) knowledge with procedural (management) knowledge. The course was designed to impart knowledge on hospitality real estate, including knowledge on urban planning, development control and regulation, financial planning, and property and facilities management. Correspondingly, green building knowledge match each

of these themes was embedded in each theme-based lecture. It appears the logical link between two sets of knowledge is not sufficiently cohesive. To strengthen their logical link, an existing case or cases that can manifest both sets of knowledge should be adopted.

### 6.2 Role of VR technologies in facilitating green building education

VR technologies are used as an innovative tool to facilitate constructivist learning. In this case, VR helps to solve important practical problems. Although site visits are commonly welcomed by students, the number of physical site visits that can be arranged per course is limited. Moreover, the arrangement of site visit is time consuming and labour intensive. Past experience tells that a considerable amount of time goes to the planning and communication with the site-in-charge. Also, previous literature demonstrates that VR can allow students to directly experience environments or situations that are difficult to represent by traditional teaching methods such as lectures and slide shows (Hamilton et al., 2021). In light of this, VR site visits provide high level flexibility at reduced cost.

The ZCB in the case study was developed to raise public's awareness of sustainable buildings and to harness green building education. It is a powerful package of green building knowledge thus suitable to be transformed into VR materials. The course instructor studied the building thoroughly, designed the "virtual tour path" and mapped out associated knowledge along the "green building path". Furthermore, instructor designed the scripts for the voice-over narration and systematically integrated the green building knowledge in the VR video. Through a site visit in the VR-aided environment, students were exposed to a completed green building project where knowledge learned in lectures was embraced as a whole.

### 6.3 Facilitating the achievement of carbon neutrality

All around the world, economies, businesses, and people's lives have been impacted by climate change. Global carbon dioxide emissions have increased by roughly 50% since 1990. Nearly 50% of annual global $CO^2$ emissions are produced by the building sector out of this total output (Architecture2030, 2022). In order to facilitate carbon neutrality, green building education should align with global agendas.

The results of this study demonstrate that by using digital technologies, such as VR technology, more students and the general public can be nurtured about green buildings. Relevant knowledge, such as energy usage, low-carbon living practises, etc., can be woven into the body of knowledge for green buildings and conveyed using a unified pedagogical framework. This study enables policy decision-makers to understand the significance of green building education and how it may soon make carbon neutrality possible. From the standpoint of green building education, pertinent policies on reaching carbon neutrality can be produced with the integration of VR technology and based on a unified pedagogical model.

## 7. Conclusion

This study focuses on a PBL approach to development of a VR-aided four-quadrant pedagogical model, which supports green building education in a university hospitality real estate course in Hong Kong. It elaborates on the implementation process, the course design components and their relationships with the PBL pedagogy. To evaluate the pedagogical model design and its implementation, nine green building professionals were interviewed and a workshop was conducted with 45 building professionals.

Investigated through a case study, the pedagogical model developed for the course is novel. It contributes to VR-aided PBL-led pedagogy development by confirming the effectiveness of the two instruments in supporting green building education. Nevertheless, barriers to the future

application of the pedagogical model in other education programmes and the further utilisation of the VR platform exist. The implementation of the pedagogical model requires the course designer or instructor to fully comprehend two sets of knowledge bodies in order to deliver effective learning activities (site visits) and material (VR video) design. Whereas the model can be expanded to integrate more pedagogical elements for implementation in other education programmes, time and resources for regular updates of the contents of the VR platform are concerns to be cleared.

Despite the above contributions, there are limitations with this study. First, the course evaluation was conducted from the green building professional and educator's perspectives. While this is a credible way of external evaluation, students' feedback should be obtained in future to identify any improvement for the pedagogical model from the course learners' perspective. Second, the pedagogical model was implemented in one course of the HRE programme. Future work should be carried out to incorporate the pedagogical model into other education programmes, especially those with less relevance to the built environment curriculum, to prove the model's effectiveness in facilitating teaching and learning. Third, the VR platform contains green building knowledge of only one site, which is the ZCB. The VR platform should be expanded to cover more green building cases, by then multiple case studies could be conducted to further illustrate a wider application of the pedagogical model. Additionally, more environmentally friendly structures (e.g. green buildings) should be included to aid in the execution of next technical site visits.

**References**

Architecture2030. 2022. Why the Built Environment, available at :< https://architecture2030.org/why-the-building-sector/>, last accessed on October 29, 2022.

Bas, G. 2011. "Investigating the effects of project-based learning on students' academic achievement and attitudes toward English lesson." *The Online Journal of New Horizons in Education* 1(4): 1–15.

Bloom, B. S., Englehard, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. 1956. Taxonomy of educational objectives, handbook I: The cognitive domain. New York, NY: Longmans.

Bloor, M. and Wood, F. 2006. Keywords in Qualitative Methods, SAGE.

Brundiers, K. and Wiek, A., 2013. "Do we teach what we preach? An international comparison of problem-and project-based learning courses in sustainability." *Sustainability 5*(4): 1725-1746.

Chua, K.J. and Islam, M.R. 2021. "They hybrid project-based learning-flipped classroom: a design project module redesigned to foster learning and engagement." *International Journal of Mechanical Engineering Education* 49(4): 289-315.

Cole, L. 2013. "The green building as a medium for environmental education." *Michigan Journal of Sustainability*, *1*.

Cole, L.B. 2019. "Green building literacy: a framework for advancing green building education." *International Journal of STEM Education 6*(1): 1-13.

Cole, L.B. and Altenburger, E. 2019. “Framing the Teaching Green Building: Environmental education through multiple channels in the school environment.” *Environmental Education Research 25*(11):1654-1673.

Cole, L.B. and Hamilton, E.M. 2020. “Can a green school building teach? A pre-and post-occupancy evaluation of a teaching green school building.” *Environment and Behavior 52*(10): 1047-1078.

Cole, L.B., Coleman, S. and Scannell, L., 2021. “Place Attachment in Green Buildings: Making the Connections.” *Journal of Environmental Psychology* 101558.

Fosnot, C. T. 2013. Constructivism: Theory, perspectives, and practice. Teachers College Press.

Fowler, C., 2015. “Virtual reality and learning: Where is the pedagogy?” *British journal of educational technology 46*(2): 412-422.

Frank, M., Lavy, I. and Elata, D. 2003. “Implementing the project-based learning approach in an academic engineering course.” *International Journal of Technology and Design Education* 13(3): 273-288.

Goedert, J. D., Pawloski, R., Rokooeisadabad, S., and Subramaniam, M. 2013. “Project-Oriented Pedagogical Model for Construction Engineering Education Using Cyberinfrastructure Tools.” *Journal of Professional Issues in Engineering Education and Practice* 139(4): 301-309.

Gratchev, I. and Jeng, D.S. 2018. “Introducing a project-based assignment in a traditional taught engineering course.” *European Journal of Engineering Education* 43(5): 788-799.

Guo, P., Saab, N., Post, L.S. and Admiraal, W. 2020. “A review of project-based learning in higher education: student outcomes and measures.” *International Journal of Educational Research* 102:101586.

Halabi, O., 2020. “Immersive virtual reality to enforce teaching in engineering education.” *Multimedia Tools and Applications 79*(3): 2987-3004.

Häkkinen, T. and Belloni, K. 2011. “Barriers and drivers for sustainable building.” *Building Research & Information 39*(3): 239-255

Hamilton, D., McKechnie, J., Edgerton, E. and Wilson, C. 2021. “Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design.” *Journal of Computers in Education 8*(1): 1-32.

He, B.J., Zhao, D.X., Zhu, J., Darko, A. and Gou, Z.H. 2018. “Promoting and implementing urban sustainability in China: An integration of sustainable initiatives at different urban scales.” *Habitat International 82*: 83-93.

Hou, H. and Wu, H. 2020. “Technology for real estate education and practice: a VR technology perspective.” *Property Management 38*(2): 311-324.

Hou, H. and Wu, H. 2021. “Tourists’ perceptions of green building design and their intention of staying in green hotel.” *Tourism and Hospitality Research 21*(1): 115-128.

International Energy Agency. 2021. Buildings – A source of enormous untapped efficiency potential, available at :< https://www.iea.org/topics/buildings>, last accessed on August 22, 2021.

Ismail, M.A., Keumala, N. and Dabdoob, R.M. 2017, "Review on integrating sustainability knowledge into architectural education: practice in the UK and the USA", *Journal of Cleaner Production*, Vol. 140, pp. 1542-1552.

Johnston, E., Olivas, G., Steele, P., Smith, C. and Bailey, L. 2018. "Exploring pedagogical foundations of existing virtual reality educational applications: A content analysis study." *Journal of Educational Technology Systems 46*(4): 414-439.

Jones, L. and Wong, W. 2016. "More than just a green building: Developing green strategies at the Chinese University of Hong Kong Library." *Library Management* 37(6/7): 373-384.

Kevern, J.T. 2011. "Green building and sustainable infrastructure: Sustainability education for civil engineers." *Journal of Professional issues in engineering education and practice 137*(2): 107-112.

Krajcik, J., & Shin, N. 2014. Project-based learning. In R. K. Sawyer (Ed.), Cambridge handbook of the learning sciences (2nd ed., pp. 275–297). New York, NY: Cambridge University Press.

Kubiatko, M., and Vaculová, I. 2011. "Project-based learning: Characteristic and the experiences with application in the science subjects." *Energy Education. Science and Technology Part B: Social and Education Studies* 3(1): 65–74.

Landrum, N.E. and Ohsowski, B. 2017. "Content trends in sustainable business education: an analysis of introductory courses in the USA." *International Journal of Sustainability in Higher Education* 18(3):385-414.

Leite, F., 2016. "Project-based learning in a building information modeling for construction management course." *The Journal of Information Technology in Construction 21*:164-176.

Lepe, E.M. and Jiménez-Rodrigo, M.L. 2014. "Project-based learning in virtual environments: a case study of a university teaching experience." *International Journal of Educational Technology in Higher Education 11*(1):76-90.

Lindsay, G., Cole, L.B., Akturk, A. and Akin, H., 2021. "Pressing issues: Setting a sustainability agenda through *media* coverage of green science museums." *Applied Environmental Education & Communication*1-14.

Liu, Y., Lou, S., Shih, R., Meng, H., and Lee, C. 2010. "A case study of online project-based learning: The beer king project." *International Journal of Technology in Teaching and Learning* 6(1):43–57.

Lu, M. and Lai, J.H.K. 2019. "Building energy: a review on consumptions, policies, rating schemes and standards." *Energy Procedia* 158: 3633-3638.

Luo, Y. and Wu, W., 2015. "Sustainable design with BIM facilitation in project-based learning." *Procedia engineering 118*: 819-826.

Mujika, M.G., Oxinaga, X.G., Uria, E.S. and Manso, A.P. 2013. "Developing teamwork efficacy factors: An experience in a project based learning context." *The International journal of engineering education* 29(3): 752-762.

Oktay, D. 2020. Architectural Education for Sustainability. In: Sayigh, A. (eds) *Renewable Energy and Sustainable Buildings*. Innovative Renewable Energy. Springer, Cham.

Pektaş, Ş.T., Aybar, N.Ş., Savut, N.Y. and McKinnon, H. 2015.Integrating green building approaches to interior architecture education: a cross-cultural study. Open House International.

Ravitz, J. and Blazevski, J., 2014. "Assessing the role of online technologies in project-based learning." *Interdisciplinary Journal of Problem-Based Learning 8*(1): 9.

Sanchez, A., Barreiro, J.M. and Maojo, V. 2000. "Design of virtual reality systems for education: A cognitive approach." *Education and information technologies 5*(4): 345-362.

Shuell, T. J. 1986. "Cognitive conceptions of learning." *Review of Educational Research* 56(4): 411–436.

Tseng, J.L., 2020. "Raising the Learning Effects for Learners with Low Entrance Scores using Project-Based Learning in Virtual Reality Practice." *IAENG International Journal of Computer Science 47*(3).

Üçok Hughes, M., Upadhyaya, S. and Houston, R. 2018. "Educating future corporate managers for a sustainable world: recommendations for a paradigm shift in business education." *On the Horizon* 26(3): 194-205

Xie, X., Qin, S., Gou, Z. and Yi, M. 2021, "Incorporating green building into architectural education: what can we learn from the value-belief-norm theory?", *International Journal of Sustainability in Higher Education*, Vol. 22 No. 3, pp. 457-476.

ZCB, (2022). Zero Carbon Building VR video, available at: <https://s3.ap-southeast-1.amazonaws.com/zcb/zcb.htm>, last accessed on March 18th, 2022

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