Pedagogical issues in using immersive virtual environments in architectural education

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In architectural education Immersive Virtual Environments (IVE) can present the student with a perspective image, which changes as he/she freely navigates through any design and interacts with it. The model is large enough to boost the student's ability to conceive three-dimensional spaces and allows the instructor to critique the design and discuss modifications. Reports about using IVE systems in architectural education are still very rare even from the few educational institutions that acquired one of these systems. Based on the experiences gained from the UAEU-CAVE experiment, this paper argues that IVE systems can be effectively used in architectural education only if certain technical, cultural and pedagogical/methodological requirements are met and that lack of progress in any of these categories can hinder benefiting from the system capabilities. The paper focuses on the pedagogical/methodological issues related to learning/design theories which will guide the development of Virtual Reality (VR) applications that will help achieving the learning/design objectives. Four different types of setups have been identified and discussed. Two setups were found to be suitable for the classroom and two more setups suitable for the design studio. Findings from two different courses taught using the UAEU-CAVE are presented to guide future work in the same area.

يمكن للبيئات الإفتراضية الإنغماسية أن تقدم لطلاب العمارة صورة منظورية تتغيير أثناء تحرك الطالب بحرية داخل أى تصميم والتفاعل معه. ويكون عرض التصميم بحجم كبير لتعظيم قدرة الطالب على فهم و إدراك الخصائص ثلاثية الأبعاد للفراغ وهو ما يتيح للمعلم أن ينقد التصميم المعروض و يناقش التعديلات المقترحة. وتعد التقارير عن إستخدامات تلك التقنية فى التعليم المعمارى نادرة جدا" حتى من الجامعات التى قامت بشراء تلك الأنظمة. وبناء على الخبرة التى تم التعرض لها من خلال تجربة لتلك الأنظمة يناقش البحث ثلاث متطلبات أساسية تقنية و سلوكية وتربوية يجب توفرها حتى يمكن الإستفادة من إمكانات تلك الأنظمة فى التعليم المعمارى. ويركز البحث على القضايا التربوية و أساليب إستخدام تلك الأنظمة للوصول إلى الأهداف التعليمية المطلوبة. وقد تم تحديد أربعة مجالات للتطبيق إثنان منها يصلحان للإستخدام فى الفصل للمواد النظرية و إثنان يصلحان للإستخدام فى مشاريع التصميم المعمارى. وينتهى البحث بعرض نتائج إستخدام بيئة إفتراضية إنغماسية فى مادتين دراسيتين لتساعد على توجيه أبحاث مستقبلية أخرى فى نفس المجال.

Keywords: Immersive virtual environments, Virtual Reality, CAVE, Architectural Education, Pedagogy

1. Learning theories in architectural education

Behaviorism, cognitivism, and constructivism are three learning theories which are relevant to architectural education. In the behaviorism approach the student is regarded as an empty container to be filled with knowledge from the teacher. Learning happens when a correct response is demonstrated following the presentation of a specific environmental stimulus. This approach can still be found in architectural education in many of the subjects taught in the traditional classroom, where students are expected to learn established facts, concepts and procedures. Behaviorism is considered adequate for achieving learning at the lower two or three levels in Bloom's cognitive domain which identifies six successively higher levels of understanding; knowledge – comprehension – application – analysis – synthesis - evaluation [1]. In the cognitivism approach, learning is defined as a change in the learner's state of knowledge covering the entire cognitive domain. This approach is based on how the mind receives, organizes, stores and retrieves information in a meaningful way, developing an ability to see information from different perspectives. Using a cognitive approach in a history class for example, students might be encouraged to consider how the availability of building materials has affected traditional building techniques. Constructivism takes the view that learners build personal interpretations of the world based on individual experiences and interactions. The instructor's role changes from being a conveyor of knowledge to a facilitator of an educational experience which promotes the development of the learner's thinking skills using techniques such as problem-solving, experiential learning and discovery. Because architectural design is an ill-structured domain, most principles of constructivism such as building tacit knowledge and learning by doing were already embedded in the architectural design studio culture decades before the emergence of constructivism as a learning theory in the early 1990s. In recent years constructivism techniques are seen to be playing an increasing role in theory courses in architectural curricula. This paper discusses the support Virtual Reality (VR) in general and Immersive Virtual Environments IVE in particular can provide for the shift towards constructivist learning in architectural education both in class and in the design studio.

2. Potentials of VR in architectural education

Considering the traditional methods used in architectural representation, which were mainly static two-dimensional representations of dynamic three-dimensional spaces and volumes, it was difficult to reach the ultimate aim of an architectural education, which is to teach students to see, think and work in space. As a result, most students struggle to think in three dimensions as they design. Preliminary observations indicate that computers providing full field of view, motion, stereoscopic vision, and interactivity can convey relevant information to students more efficiently than traditional techniques [2]. In the design studio virtual reality has the potential to develop into a tool for intuitive, interactive and realistic evaluation and exploration of existing and non-existing 3D environments [3]. It allows the students to immerse themselves in the designed space in a manner similar to the way in which the space would be used [4]. The mobility in space-time it provides enhances the spatial experience and is necessary for the apprehension of this space [5].

3. Requirements for integrating VR in architectural education

The use of digital media has spread throughout schools of architecture worldwide. However, this is not an indication that potentials of using digital media in architectural education are fully exploited. The author’s reflection on the experiences gained from the UAEU-CAVE fig. 1 experiment has led to the hypothesis that virtual environments can be effectively used in architectural education only if certain technical, cultural and pedagogical/methodological requirements are met and that lack of progress in any of these categories can hinder benefiting from the capabilities of VR. Technical issues relate to accessibility to and usability of immersive virtual environments and digital design tools. Cultural issues relate to the acceptance of digital media in general and VR technology in particular and its integration in the design studio and the classroom. Pedagogical/methodological issues relate to learning/design theories which will guide the development of VR applications that will help achieving the learning/design objectives.

Fig. 1 UAEU-CAVE Layout. The immersive virtual environment in back ground driven by a cluster of graphic workstations in the foreground.

3.1. Design environment and tools

Compared to early systems developed in the early 1990s current models of projection-based VR systems are less costly. However, commercial systems are generally still restricted to use by the high-performance research community [4]. It is estimated that only about 3% of universities worldwide teach VR today [6]. More recent efforts based on systems developed in house focused on making the VR environment as easy, cost effective, and convenient as possible for users so that they can realize the benefits of big-screen VR [7]. The principal goals in building such systems are: 1) maintaining affordable cost by using standard off-the-shelf components; 2) ease of use by employing familiar computing environment (Windows) and support for applications with which the students are familiar such as Autocad and 3D Studio; and 3) continuous access by students. One can argue that advocates of integrating VR in architectural education will soon be having harder time dealing with cultural and pedagogical issues rather than with technical issues pertinent to the availability of immersive virtual environments and VR applications. However, virtual tools for immersed interactive architectural design remain in a primitive state of development.

3.2. Digital design culture

The culture of an organization comprises the attitudes, experiences, beliefs and values that are shared by people and groups in that organization. Integrating immersive virtual environments into architectural education requires an established digital design culture within the school or department of architecture. The introduction of CAD within the creative environment of design studio culture in the early 1980s was not met with much enthusiasm by the majority of faculty. CAD was perceived as the domain of technicians and has been isolated from the main thrust of design teaching [8]. For many years students were not allowed to use computers in design [9]. Later, faculty tended to blame the computer for the shortcomings of students in the use of traditional media. After two decades, and in spite advancements in CAD systems and attitudes towards digital media, Qaqish [10] still raised the issue of conventional design studio hardliners teaching advocates whose outlook and impressions undermine and deplete effective CAD integration and their negative impact obstructs in many instances CAD integration into the design curriculum. CAD for many still means electronic drafting [6]. However, attitudes in most schools are currently changing to a more balanced and opportunistic use of digital and physical media. As a result, 3D-modellers, 3D-scanner, immersive virtual environment and rapid prototyping are increasingly being used to assist students and instructors to explore and study architectural creativity in a new way. In some schools digital media have already become very traditional [11].

3.2.1. Students and faculty attitudes

Students enrolling in architectural programs are increasingly computer literate. Growing up in an age of digital media, they expect to be introduced to appropriate digital tools used in their profession. This represents a great challenge to academics who have to consider how to respect this expectation and to design the course, establish its pedagogic objectives, configure its computational environment, monitor the students' progress, and evaluate their courses. In most cases the instructor is expected to learn about the functionalities of the computer and acquire new skills or aids to supplement his knowledge about technical functionalities. A growing dilemma, however, is that many students of architecture seem to know digital tools and gadgets better than their educators [11]. This can lead to controversial classroom situations where educators manage the content, but not the tool. Even those educators with digital design expertise face the dilemma of becoming obsolete once new and more powerful software or hardware solutions are introduced [12]. There is therefore constant need for training educators to keep ahead advances in technology and to take up the challenges afforded by VR. Institutions have to acknowledge that, in addition to providing training to their staff, time and assistance by specialists are also necessary to develop VR material and content to be used in the classroom or in the design studio.

3.2.2. Integration of digital media in the architectural curriculum

The most distinctive mode of architectural education is the well-established tradition of project-based teaching in the design studio. Design studios serve as a melting pot of all the technical skills offered in tributary courses. Till the early 1990s a typical curriculum in architecture used to offer courses in freehand drawing, perspective drawing, and rendering techniques. Today many architecture curricula offer a single drawing course with concentration toward learning the drawing conventions, perspective, orthographic drawings, etc. while digital design media has claimed at least one required course [9]. The applications of computers within the architecture curricula typically focused on skill building and were taught independently of design. Computer-based classes were usually set up to teach geometrical modeling, three-dimensional visualization, animation, energy and lighting analysis, GIS, computer graphics, digital image processing, and the use of digital video, scanning and output media. Organizing computer-related subjects as a chain of stand-alone compulsory and elective courses became an established technique in the structure of architectural curricula [5] and [6]. Typically design studios make digital media required in the final design representation.

Because this mode of teaching reinforces the perception that CAD is a presentation technique and tool that is separate from architectural design and because learning any software program becomes an end in itself, a clear trend in recent years has emerged in which the focus is shifting toward the integration of digital tools with the design process [13, 14]. This new approach perceives CAD as knowledge building, not skill building which is taught during the whole span of architectural education as a component part of almost every other subject in the curriculum. This stimulates the interest in architectural design and enhances the quality of the architectural design produced.

3.3. Pedagogy and design methods

The structure of most architectural curricula consists of; a) groups of tributary courses typically taught in classrooms where students acquire technical skills and b) a core of design studios which serve as a melting pot for all knowledge acquired. To investigate how immersive virtual environments serve both setups, the UAE-CAVE has been used in two different courses as a start. The first was the elective course "Selected Topics in Architecture". The generic nature of this course gave the author some space for experimentation which was not available in other theory or design courses with preset educational outcomes. The second course was one of the "year 2 design studios". Both experiments gave insights into the potentials of VR applications in architectural education.

4. Use of IVE in the classroom

Two methods can be identified for the use of VR in the classroom. In the first method, students use pre-developed VR applications to visit a virtual world and learn some basic concepts or develop an understanding. In the second method students are required to develop their own virtual worlds to guide the research, understanding, and demonstration of their grasp knowledge.

4.1. Use of pre-developed virtual worlds

The course "Selected Topics in Architecture" was re-designed to introduce students to the theoretical aspects of VR as well as hands-on use of the software and the management of VR projects. Students were asked to search online for the best examples of free virtual environments available in five different categories; Urban Design, History of Architecture, Building Construction and Architectural Design. The best 25 models were added to a database and a hypertext file was developed to work as an interface to start different virtual worlds as seen in fig. 2. Some of these virtual worlds used radiosity texture maps to increase the realism in the VR presentation. Other virtual environments had interactive features. These pre-developed virtual worlds provided a

Fig. 2. Interface of the database of virtual worlds.

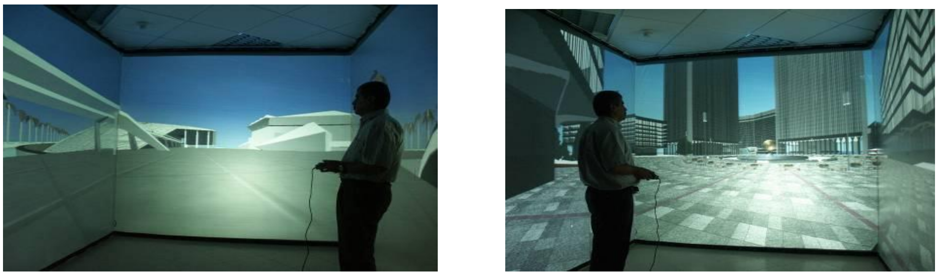
good first step for the author and students in building their understanding of the technology, and a more controllable venue for investigating basic questions pertaining to educational uses of VR technology.

Most of the virtual worlds in the database offered simple walkthroughs but no interaction features and no embedded pedagogy. Still they were found to be very effective in supporting educational objectives in different subjects fig. 3. Examples of this category are; a virtual model of villa Savoy, a model of the Chapelle Notre-Dame-du-Haut both designed by Le Corbusier, a model of the new Bibliotheca Alexandrina design by Snoheta, a model of the twin towers at the world trade center in New York including the plaza in front of them and a virtual model of the entire German city of Reutlingen (courtesy of Cybercities). These virtual models allowed students to get immersed and to navigate through them in order to experience the space, evaluate visual aspects and spatial organization of the design and to review several urban and architectural concepts considered in courses such as history, theory, urban design, building construction and structures. Students were able to study recognized works of architectural design theory without the need to travel. For example, in the villa Savoy model students were able to see features such as wide windows and the pilotis (supporting columns) from different view points, and then consider the impact of using concrete on the design. This allowed them to understand concepts such as "the garden running under the house". Two pedagogical approaches within the constructivist philosophy can enhance the effectiveness of VR in supporting educational objectives; guided-inquiry and experiential learning.

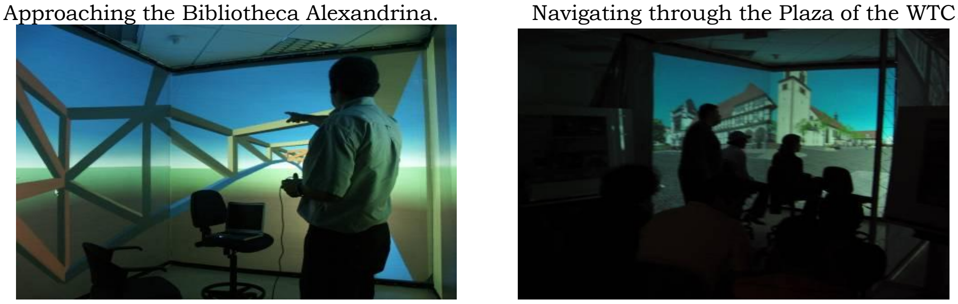
4.1.1. Guided-inquiry

In the guided-inquiry approach students are asked to perform tasks within the virtual worlds and while doing so they are guided to uncover critical concepts for themselves [15]. This could be done by providing students with a one-page list of things to do and see in the virtual world and a short list of questions to answer.

The pedagogical support to the walk-through can be provided in different ways; a) by direct guidance from the instructor, b) by means of associated printed textual materials, c) by means of links to resources embedded into the virtual world such as hypertext information, notes, photographs, and materials data sheets and drawing. This material can be presented alongside the virtual world. Students are guided in developing their own critical thinking skills by answering questions. For example in the villa Savoy model students could be asked what characteristics of reinforced concrete made the concept of "the garden running under the house" possible. Another good example was a 3D model of the Great Pyramid fig. 4, the inside of which is hollow showing various passageways and chambers. In addition to free navigation through the narrow and sloping passageways, it also offered virtual guided tours and a virtual navigation tool showing the location of the user in plan and section.



Approaching the Bibliotheca Alexandrina. Navigating through the Plaza of the WTC.



Learning basic structural Students in a virtual tour to a European city.

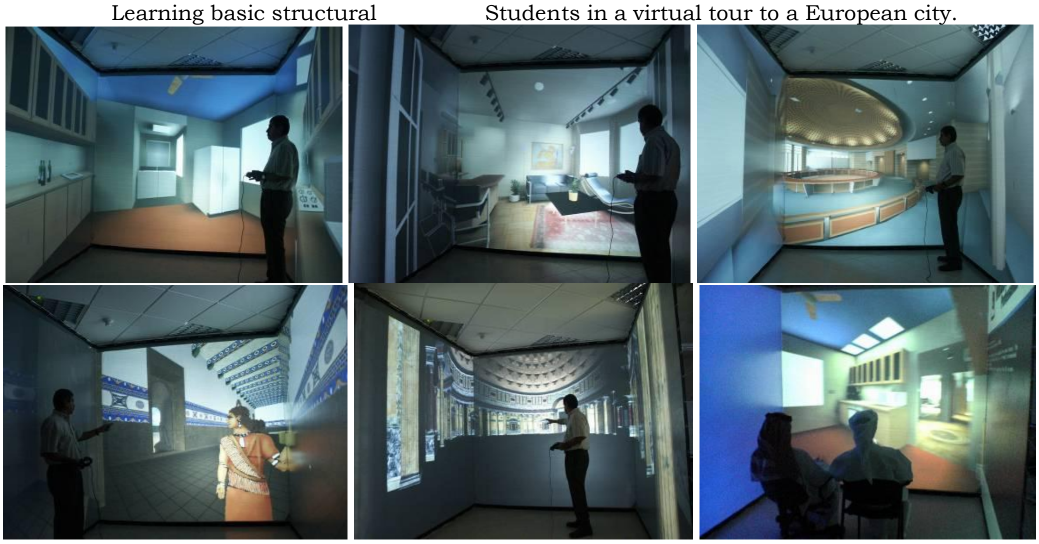


Fig. 3. Experiencing spaces in different types of buildings.

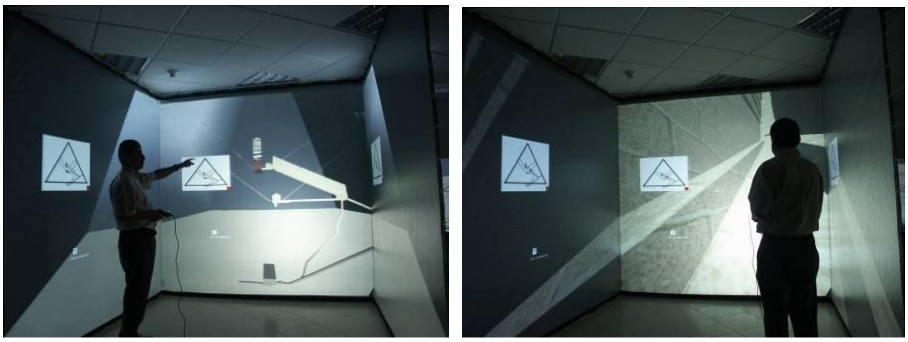


Fig. 4. Navigating through the great pyramid in Giza. Cross section enhances user orientation and understanding.

4.1.2. Experiential learning

Experiential learning refers to learning in which the learner is directly in touch with the domain being studied [16]. While all virtual worlds allow a user to experience a virtual situation, the term “experiential learning” here refers to more than simple walkthroughs of a virtual world. Educational VR applications described as experiential require some further interaction on behalf of the student [15]. A good example found in the UAEU-CAVE database was a 3D model which allowed students to assume the role of different types of users of approaching a building (Pedestrian, car driver, adult, child, wheelchair user) and to interact with the virtual model to learn more about accessibility issues. As soon as the student came close to a certain object the virtual world would display minimum and maximum dimensions allowed by the building codes and offers hyperlinks to the appropriate clause in the codes fig. 5.

Learning-by-doing and reflective inquiry can both induce learning and support mastery of complex scientific concepts. An application following an experiential paradigm is the virtual acoustics world the author is currently developing. This is a virtual world which allows the student to partially or fully fold and unfold walls and ceiling panels of sound absorbing material and to immediately hear the effect of such actions on acoustical phenomena such as reverbration and echo within the room. Another application allows students to manipulate variables such as saturation, and brightness of objects in the virtual world with the objective of learning about colour schemes in an interior design class. A third application allows the student to size shading devices and test them on different times of the year and of the day. Other applications may link the 3D model to sophisticated software for the thermal, lighting and acoustics properties of the building. This would allow the student to visualize, dynamically, airflow, temperature gradients, lighting levels and to experience the actual acoustic characteristics of the space while moving through it.

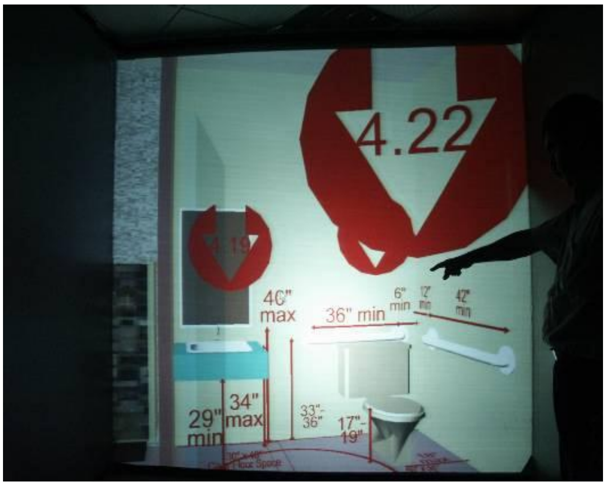


Fig. 5. Building regulation information embedded in a virtual world with links to hypertext material available on the internet.

4.1.3. Interactive behavior

Developing interactive virtual worlds to support experiential learning requires embedding dynamic behavior in these worlds. This adds the time dimension to static virtual worlds in the form of preprogrammed behaviors. In a typical example of a dynamic behavior, movable objects within a building such as doors can swing or slide open; in addition the action of a door opening could trigger other actions such as uploading of data-file and starting a narration or commencement of a guided walk through the building to illustrate use of internal space.

Applications using dynamic behaviors in architectural education can be endless and the following are only a few examples:

- removing roof or wall to view interior layout of building,
- removing layers to explore hidden materials in doors, floors, walls, and roofs,
- movement of elevators, vehicles,
- showing the working of equipment in a construction site or the traffic situation in a street,
- simulation of construction processes and their sequences,
- simulation of assembly and disassembly sequences of building components,
- simulation of operation mechanisms of building components.

One of the virtual worlds in the UAEU-CAVE database demonstrated how VR can be used to compare design alternatives. It allowed navigation through the streets of the historical center of a European city. The model had a street with moving cars going through a plaza. Virtual control panels were placed at the corners of the plaza to be used by the immersed users to switch on and off a proposed modification of plaza. Interacting with the panel removed the street and the cars and introduced shaded sitting areas, a cafe and a children playground instead. The virtual panels also had buttons for the commencement of a guided walkthrough the area and a guided fly over.

In building construction, the main objective of interactive virtual worlds is to show in an easy way and as complete in details as possible several construction processes [17]. Using such virtual worlds students can interact with the virtual building component and impose any sequence time in the construction process, and manipulate the camera as desired in order to observe conveniently any detail of the components configuration. While the animation is in process, the construction information associated to each step is listed.

4.2. Student development of virtual worlds

A variety of educational goals can be reached by encouraging students to develop their own virtual worlds to demonstrate knowledge they have acquired as part of their regular classroom activities. Such virtual applications are often used in subsequent classroom activities. Examples of some of the virtual worlds that have been developed by students include models under the theme "Motion in Architecture" fig. 6. Students selected recognized works of architectural design in which moving elements play an important role. They then demonstrated their understanding of these mechanisms by developing virtual models that provided walk-throughs in these buildings. Users were able to interact with the building elements to make these parts move as the original designer intended.

5. Use of IVE in the design studio

Despite the fact that the use of virtual reality in the classroom is increasing quickly in other fields, in architecture, educators have focused more on a bigger challenge which is utilizing it in the design studio.

5.1. Virtual design studios and electronic discussion

Development and experimentation with Virtual Design Studios (VDS) emerged in the early 1990s. In this metaphor, groups of students from different universities are immersed not into virtual buildings but into distant existing design studios using computer -mediated collaborative environments. This allows students to interact and work together with their partner groups on the same design tasks. VDSs can range from simply using email for project communication to a collaborative virtual world using video teleconferencing resources setting and web based interactive methods of drawing on the same "white board" and methods of sharing images and three-dimensional models. Experiments in online architectural education also include extending the traditional design studio and the traditional classroom through the application of online electronic discussions in different subjects. This metaphor falls beyond the scope of this paper since 'immersion' here is into a distant existing world rather than into a virtual world.

5.2. Immersive design environments

5.2.1. The CAD-VR cycle

A main concern in the design studio is that students tend to think of their designs in 2D and are overwhelmed during the transition from 2D to 3D with the complexity of what must be understood in 3D. Visual appraisal in an immersive virtual environment can help bridge this gap and reveal aesthetic and functional problems present in a design proposal. This encourages students, as designers and perceivers at the same time, to study and test conceptual details increasing the creativity and success of their designs. Solutions that enable students to use VR during the design process to experience designs developed using CAD have been described by [3] and [7]. This approach known as the VR-cycle allows students to switch from AutoCAD via 3DStudio Viz to a VR format and load it into an immersive virtual environment in a few minutes. After the student moves through the design and understands its spatial qualities, he can then go back to the drawing keyboard and make revisions, all in a matter of minutes. Using the CAD-VR cycle approach, design proposals of a group of the second year students were tested and critically discussed in the UAEU-CAVE immersive environment offering them new stimuli for both designing and enriching their learning experience fig. 7.

The CAD-VR approach raises the question of the relation between conception and representation because it uses the immersive virtual environment to display what has been previously designed with other media (sketch on paper, physical model and CAD). The influence of the immersive virtual environment in the design is therefore reduced to a minimum.

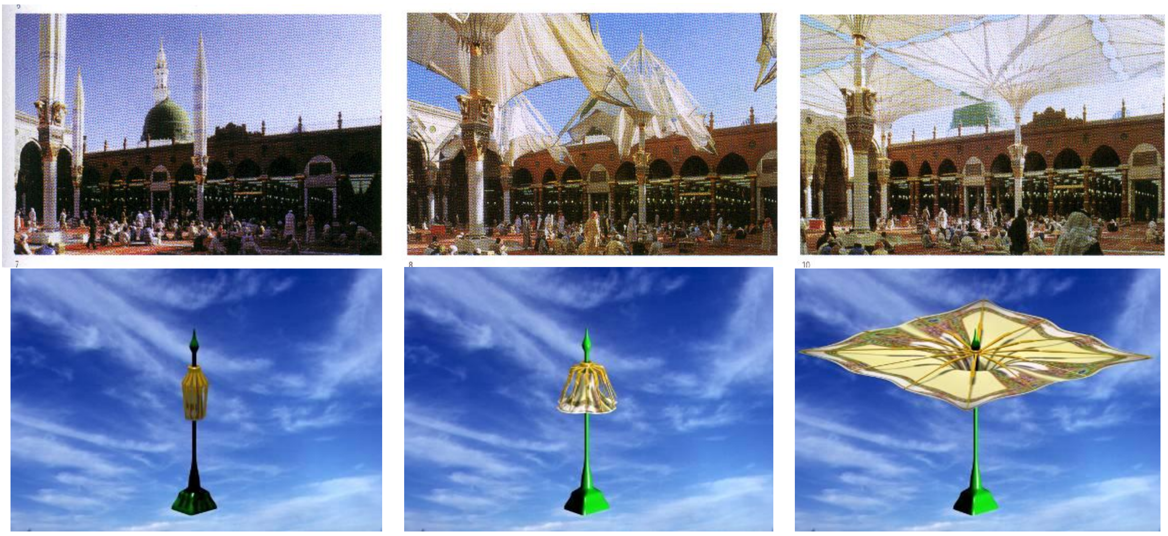


Fig. 6. Student developed virtual worlds to demonstrate their understanding of architectural knowledge. Upper row: the unfolding umbrella designed by Bodo Rash shading the courts of the main mosque in Madina, Saudi Arabia. Lower row: Student reproduction of the folding/unfolding mechanism.

Fig. 7. A student navigates through his design proposal. Students and instructor immersed in a design proposal by one of the students.

5.2.2. Immersive interactive design

Because the direct and instantaneous translation of a design idea into a 3D form plays a key role in the education and development of architectural design, a more advanced approach would be to carry out all the conceptual part of the design process in an immersive environment. This approach would encourage students to design directly in 3D from the beginning of conceptualization. It would allow students to assemble, manipulate architectural elements within the virtual world and test a number of compositional arrangements in a highly immediate design environment in a three dimensional context with a high degree of spatial presence. While this scenario appears to be possible and very promising, the software solutions required are still not readily available. Techniques of 3D-modelling, rendering, animation and panoramic views currently incorporated in the majority of software used in architecture provide visual realism, but they do not offer other capabilities like interactivity and sense of immersion.

On the other hand most immersive virtual worlds offer some tools to control navigation and to interact with objects in the pre-prepared virtual world but no tools for creation and manipulation of objects while the virtual world is being used. A few attempts to bridge this gap can be seen in the literature [18] and [19]. An example of these early experiments is proposed by Dobson [8]. His approach is based on a small library of architectural elements. Having prepared a library of 3D elements, architectural compositions are then produced based upon this object set. Other approaches are based on gesture recognition as a trigger to execute commends or control structured menus within the immersive virtual environment. A more recent approach is proposed by Dorta and Perez [20] and allows sketching with pencil on panorama templates while being immersed in a virtual world and perceiving the sketch in full size immediately. All these solutions, however, do not offer the full modeling functionality of a CAD system. The designs created are not as sophisticated as those produced using traditional CAD and rendering software. More research is needed to overcome these shortcomings and allow designers to shift the focus toward the integration of immersive virtual environments with the design process rather than having most of the emphasis placed on the medium itself. This is necessary in order to reduce the risk of students not achieving the educational objectives behind the design project.

6. Discussion and conclusions

The outcomes of the UAEU-CAVE experiment, offer a contribution to the debate on the concept of using Immersive Virtual Environments in Architectural Education. The main findings show that immersive virtual environments could be used from basic courses until advanced subjects, in the diverse lines of architectural education; in the classroom as well as in the design studio. Findings also show that students enjoy both experiencing pre-developed applications as well as developing their own virtual worlds. The enjoyment was even higher when students had their own design project loaded into the immersive virtual environment. Use of VR seems to serve as a challenging and motivating factor. Some students, however, reported slight to moderate levels of discomfort due to simulator sickness during the first one or two times in the CAVE but this disappeared in the following sessions. Pre-developed virtual worlds can address complex subjects and provide the student with methods of guided-inquiry and experiential learning. Students' comments were positive and they developed a better understanding of architectural spaces. However, students found that a hybrid approach using mixed forms of representations of information such as plans, sections, elevations, 2D renderings, books, photographs, etc. to support, supplement and extend the representation of the immersive virtual world, is more successful in teaching than using only one form of representation of information.

Making students develop virtual worlds as part of their learning activities to demonstrate knowledge they have acquired was found to be effective in making them learn the content they were expected to learn although this might be because of the research, world design, and world construction activities rather than experiencing the developed worlds which are usually simple.

Although the CAD-VR cycle approach is not straightforward and extends the conventional workflow of the design process, it was found to be very valuable. It allowed students to experience and to understand the spatial qualities of their own designs differently and much more comprehensively than non-immersive environments. The full-scale experience of design proposals made it clear that each stroke they had made had an impact on the design. Students felt that they were being part of their design and communicating directly with it. The critiquing process was also enhanced because students were able to describe and demonstrate their projects to their audience much more effectively.

For immersive interactive design, VR technology appeared to be still maturing and has not yet reached a level which allows it to support this approach. Most investigations in this area still focus on the technology itself rather than examining the effectiveness of the technology as a tool for design and for learning. Applications tested in this category showed that small changes in position, orientation, size, color, or texture of simple objects was simple to make and provided immediate feedback. Large changes to geometry and creation of conceptual designs were generally difficult and cumbersome. Although most students were able to appreciate both the limitations and potential of VR technology, some students spent a longer time learning how to use the technology, which affected their focus on design. Most students considered the immersive virtual environment more useful for presentation and visualization of built or proposed designs than for making design decisions. Some students and faculty expressed concern that the novelty of the system was counterproductive as it caused the lack of useful critiquing because critics seemed amazed by the environment. Developing a CAD system combining traditional desktop modeling with an immersive option would be useful and allow the strengths of both environments to be exploited.

Some faculty expressed concerns that the use of the immersive virtual environment in the design studio could undermine the use of hand drawing. Producing fast, yet credible free-hand perspective drawings during desk critics or in early stages of schematic design is a skill that, previous generations of students had but a large and growing number of current students lack. This skill needs to be preserved as it closely relates to the ability to design. Attitudes in the design studio should therefore adopt a balanced approach and maintain a philosophy of using digital and physical media on an opportunistic basis.

The effective use of immersive virtual environments requires that educators become facilitators who support students in their discovery of worlds and building ideas and also to develop appropriate strategies and conceptual frameworks within which their application becomes meaningful for architectural education. Educators must have adequate expertise in computer technology, and also be able to confront issues pertinent to architectural education. This change in the role of the educators points out the need to prepare faculty for these new types of activities. Institutions need to provide different types of resources including; a) funding for relevant research and for purchasing equipment, b) training programs for faculty, and c) incentives to encourage faculty to invest time and effort in developing solutions and teaching material.

7. Future work

The use of immersive virtual environment in architectural education is still new and it does not seem that the full potential and implications of Virtual Reality has been exploited. There are many gaps that need to be filled by findings from more structured investigations in different sub-areas. The following is only an example of possible research areas that need to be addressed:

- Identify categories of students, “high-ability”, “low-ability”, “active,” “visual,” “inductive”, and “global”, which will benefit most from learning in immersive virtual environments.
- Work on developing the technology in

areas where it is currently not mature enough for practical use such as the use of interactive technology in the initial stages of project design.

- Identify educational objectives or material which VR best suites.
- Identify what constitutes an effective virtual learning environment for architects.
- Investigate whether interactivity or immersion plays a bigger role in the effectiveness of immersive virtual environments in architectural education.
- Measure the effectiveness of educational VR applications and how it compares with traditional instruction practices.
- Form teams of faculty and VR developers to work together in developing and testing educational virtual worlds.
- Measure student enjoyment and increased motivation and how long it lasts after the novelty factor of VR has faded.

References

[1] B.S. Bloom, Taxonomy of Educational Objectives, the Classification of Educational Goals, Handbook I: Cognitive Domain. New York: Longman (1956).

[2] L.N. Kalisperis, G. Otto, K. Muramoto, J.S. Gundrum, R. Masters and B. Orland Virtual Reality/Space Visualization in Design Education: The VR-Desktop Initiative, Connecting the Real and the Virtual - Design Education [20th eCAADe Conference Proceedings] Warsaw (Poland) 18-20 September 2002, pp. 64-71 (2002).

[3] H., Achten, W. Roelen, J.-Th. Boekholt, A. Turksma and J. Jessurun,) Virtual Reality in the Design Studio: The Eindhoven Perspective, Architectural Computing from Turing to 2000 [eCAADe Conference Proceedings] Liverpool (UK) 15-17, pp. 169-177 (1999).

[4] L. Kalisperis, G. Otto, K. Muramoto, J. Gundrum, R. Masters and B. Orland, An Affordable Immersive Environment in Beginning Design Studio Education, Thresholds - Design, Research, Education and Practice, in the Space Between the Physical and the Virtual [Proceedings of the 2002 Annual Conference of the Association for Computer Aided Design In Architecture] Pomona (California) 24-27 October 2002, pp. 47-54 (2002).

[5] J.P. Couwenbergh, A. Croegaert, B. Gallez, P. Petit and M. Tilman, The Architect, CAD and Teaching The Pedagogical Point of View at Tournai's ISA Saint-Luc, AVOCAAD Second International Conference [AVOCAAD Conference Proceedings] Brussels (Belgium) 8-10 April 1999, pp. 221-228 (1999).

[6] Horne, Margaret; Hamza, Neveen Integration of Virtual Reality within the Built Environment Curriculum, ITCon Vol. 11, pp. 311-324 (2006).

[7] A. Okeil,. Enhancing Architectural Education Using Immersive Virtual Environments: The UAEU-CAVE Experience. Proc. of the Global Congress on Engineering and Technology Education, GCETE2005, Santos (Brazil), pp. 340-344 (2005).

[8] Dobson, Adrian Exploring Conceptual Design using CAD Visualisation and Virtual Reality Modelling , Computerised Craftsmanship [eCAADe Conference Proceedings] Paris (France) 24-26, pp. 68-71 (1998).

[9] A.H. Angulo, R.J. Davidson and G.P. Vásquez de Velasco, (2001) Digital Visualization Teaching of Cognitive Visualization, Reinventing the Discourse - How Digital Tools Help Bridge and Transform Research, Education and Practice in Architecture [Proceedings of the 21st Annual Conference of the Association for Computer-Aided Design in Architecture] Buffalo (New York) 11-14 October, pp. 292-301(2001).

[10] Qaqish, Ra'ed VDS/DDS Practice Hinges on Interventions and Simplicity - A Case Study of Hard Realism vs. Distorted Idealism, Architectural Information Management [19th eCAADe Conference Proceedings/ISBN 0-9523687-8-1] Helsinki (Finland) 29-31 August 2001, pp. 249-255 (2001)

[11] E. Mark, B. Martens and R. Oxman, Round Table Session on "Theoretical and

Experimental Issues in the Preliminary Stages of Learning/Teaching CAAD", Connecting the Real and the Virtual - design e-ducation [20th eCAADe Conference Proceedings] Warsaw (Poland) 18-20 September 2002, pp. 205-212 (2002).

[12] Moloney, Jules x Charcoal, Bits and Balsa: Cross Media Tactics in the Foundation Design Studio, Architectural Computing from Turing to 2000 [eCAADe Conference Proceedings] Liverpool (UK) 15-17 September 1999, pp. 110-115, (2002).

[13] Zupancic Strojan, Tadeja and Mullins, Michael Criteria for Architectural Learning where Virtual Design Studios are Employed, Promise and Reality: State of the Art versus State of Practice in Computing for the Design and Planning Process [18th eCAADe Conference Proceedings] Weimar (Germany) 22-24 June 2000, pp. 51-54 (2000).

[14] Mark, Earl A Prospectus on Computers Throughout the Design Curriculum, Promise and Reality: State of the Art versus State of Practice in Computing for the Design and Planning Process [18th eCAADe Conference Proceedings] Weimar (Germany) 22-24 June 2000, pp. 77-83 (2000).

[15] C. Youngblut, Educational Uses of Virtual Reality Technology, Institute for Defence Analyses, Washington (1998).

[16] H. Safey El Din and A. Salama, Experiential Learning in Undergraduate Architectural Education: Cases from Egyptian Universities - Themes in Architectural Education Today - 8th Architecture & Behaviour colloquium April 8-13, 2001, Monte Verità, Ascona, Switzerland (2001).

[17] A.Z. Sampaio, P. Henriques and P. Studer, Learning Construction Processes Using Virtual Virtual Reality Models, ITcon Vol. 10, pp. 141-151 (2005).

[18] Donath, Dirk Using Immersive Virtual Reality Systems for Spatial Design in Architecture, AVOCAAD Second International Conference [AVOCAAD Conference Proceedings] Brussels (Belgium) 8-10 April 1999, pp. 307-318 (1999).

[19] H. Achten, B. De Vries and J. Jessurun, DDDOOLZ. A Virtual Reality Sketch Tool for Early Design, [Proceedings of CAADRIA 2000] Singapore 18-19 May 2000, pp. 451-460 (2000).

[20] T. Dorta, E. Perez, Immersive Drafted Virtual Reality a new approach for ideation within Virtual Reality, Synthetic Landscapes [Proceedings of ACADIA 2006] pp. 304-316 (2006).

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