Global Journal of Business and Social Science Review

GATR JOURNALS

Journal homepage: www.gatrenterprise.com/GATRJournals/index.html

Global J. Bus. Soc. Sci. Review 2 (3) 61 – 68 (2014)

Using Digital Simulation as an e-Learning Tool to Create Dynamic Learning in Architecture Students

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ABSTRACT

Objective - E-learning has been an integrated teaching and learning approach in higher educational institutions and considered as a way forward in creating life-long learners. In Architectural studies, where design is a major component, soft wares are vastly used as designing tools. Recent years saw an increasing awareness of green architecture taking into account the sustainability where the absence of or efficient technology in a building playing a major role in creating sustainable architecture. In an attempt to enhance design through technical module a traditional case study project has been converted into simulation project to create a dynamic learning much needed by Architecture students. This paper examines the value of using simulation to study the effectiveness of shading device and its effect on student's learning.
Methodology/Technique - The investigation is conducted by evaluating the learning outcome of architecture students in a private institute of higher education in Malaysia by using questionnaire to collect data from a group of 30 volunteers from 105 architectural students whom have completed the module.
Findings – The researchers found that although 90% of the students understood that sun-shading is the basic knowledge to address sustainability in a building only 80% of the student will be able to adopt it in their Architecture Design Studio. 93.3% of the student agreed to the statement that they learnt new skills by attempting this project and had highest frequency for listing software (digital simulation) followed by analytical skills.
Novelty – The paper emphasises the dynamic learning as an integrated approach to designing and an effective way to intensify life-long learning by instilling e-learning methods as a way forward in teaching and learning architecture students.
Type of Paper: Empirical

Keywords: E-learning; Architecture; Sun-Shading; Simulation; Sustainability.
JEL Classification: I20, I23, I29.

1. Introduction

Simulating in digital tool is an authentic learning experience and involves higher order of thinking skills as an e-learning method. As technology advances, it needs to be included in teaching and learning in order for graduates to fit into the current industry. Becerik-Gerber, Gerber, & Ku (2011) in their study of the pace of technological innovation in architecture, engineering, and construction education stated that integrating recent trends into the curricula explained that the increasing global emphasis on sustainable approaches and the need

* Paper Info: Received: July 8, 2014
Accepted: August 14, 2014
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to increase efficiency and improve cost over the lifecycle of projects, demand new approaches to architecture, engineering, and construction education. Emphasis on programs focusing on emerging subject areas of Building Information Modeling (BIM) and sustainability in Architecture programme in Higher Education globally also impacts the teaching and learning at higher educational institutions in Malaysia. This study intends to relate new learning experience of gaining knowledge and skills by digital simulation for architecture students and willingness to apply in their design studio. This study aims to develop a positive attitude among architecture students towards using e-learning technique in applying new technical knowledge and skills learned, in their design studio.

1.1 Architecture Design Studio Learning and Technical Studies

The most important part of the architectural student's education and the core of the architectural curriculum is the design studio. As Allen (1997) mentioned that experience has shown that students learn technical skills more efficiently and incorporate them more readily into building design process when the skills are acquired on and as-needed basis during ongoing design projects. While the importance of technical studies is undeniable, thus the researchers administered project based learning with similarities to the design project in Architecture Design Studio. While Krause (2003) emphasized that within the realm of architecture and design, technology interactions are becoming more sophisticated and that traditionally, computer/architect interaction centered on models of efficiency and documentation but recently, this interaction has shifted away from productivity tools and moved towards design exploration and experimentation.

Case study or precedent studies are often assigned as a research activity in architecture design project. Heylighen, Bouwen & Neuckermans (1999) highlights the importance of studies of case studies in formulating design ideas and concepts in architecture design that are traditionally using case study or precedent study to "emphasize that knowing components and concepts on a passive, technical–rational level enabling an architect to analyse and evaluate existing designs. Yet, it is not constructive, as it does not point the way to create a new design". The point to note in their statement is traditional way of learning by acquiring knowledge without an opportunity to test or experiment and verify the function of certain elements in designing certainly does not inform how to create a novel design. Therefore the precedent studies are seen on a surface level, as an aesthetical feature and often not by validating the functionality of the studied element in a case study. In designing, traditionally, ideas and assumptions are often heard and not verified. These concepts and ideas then can be concluded that the aesthetics of the design precedes the functionality of the said design.

The traditional act of learning passively does not encourage the development of meta-cognitive skills. As mentioned by Chance (2010) linear thinking just does not work with architecture students. The constructive mode of learning taking it further in this research emphasizing Learning by Doing is a small example of a technical study module emphasizing and realigning a case study project that can be easily replicated in Architecture Design studio with a scientific approach. This project emphasizes on the process of learning as much as acquiring the knowledge and skills. The process learnt are meant to be replicated as a process of relearning that was emphasized by Kolb in 1984 (cited in Chance, 2010). The project uses digital tool to simulate sun-shading of a case study and to evaluate and judge the intended function. In architecture design studio students can replicate the process easily and use it as a designing tool by creating and experimenting prototypes to evaluate the function and reassess the aesthetics of the building fabric. The coinciding activity of realigning a case study project in technical module using digital tool to replicate the design function and its principles are mapped in Table 1 by Kirschner, Carr and Merrienboer, (2002) by reporting Visscher-Voerman's distilled 16 design principles from her case analyses as highlighted in the table below. This then facilitates the Architecture Design Studio's learning method of Active Learning or Learning by Doing.

Table 1: Modified from Sixteen Design Principles from Visscher-Voerman in 1999 (cited in Kirschner, et al., 2002)

Design Principles by Visscher-Voerman	Project using digital simulation of sun-shading

1.	Designers should make a **prototype** in an early stage of the design process.	The digital tool can be used as a designing tool to test the prototypes of sun-shading device that best fits the function and aesthetic of the building fabric.
2.	Designers should split the design process into phases with formal decision moments and **concrete products**, and should only plan the upcoming phase in detail.	Concrete products means fully acknowledging the functionality – digital simulation tool allows testing and verifying functions thus allowing designers to move to a next phase.
3.	During the design process, designers should pay as much attention to creating ownership with clients and stakeholders, as to reaching theoretical or internal **quality** of the design.	Quality although very subjective it also facilitate the functionality.
4.	Designers should base their work in **scientific knowledge and principles** as much as possible.	Sun-shading is a basic knowledge in designing as sun is the source of heat which affects the thermal environment of user. The biggest issue of sustainability in highest energy consumption in tropical climate is to cool building through air-conditioning. Digital simulation uses scientific knowledge and principle to allow real time simulation of an actual condition. It is the way forward in teaching with technology.
5.	Even if designers have a clear idea for the (potential) solution at the start of the process, consideration of possible **alternative solutions** is essential.	Digital tool allows designer to design –test –redesign –retest ….. and conclude easier and faster than working on paper or physical model.
6.	Designers should not only ask clients and (future) users for content-related input, but should also give them the right to decide about the design itself.	NA
7.	A useful means to help clients, partners, and other stakeholders to choose a solution and to formulate product specifications is by showing products from former projects.	NA
8.	In order to clarify product specifications, designers should spend their time on carefully planned formative evaluations of **early versions of a prototype**, rather than on an elaborate preliminary analysis.	**Historical research is important but elaborate scientific analysis is possible now with digital tools in a very short time with simulations thus providing avenue for creativity, inventions, interventions and innovations**.
9.	Designers should share the responsibility for creating **favorable conditions** for the implementation of a design.	Favorable conditions can be simulated in digital tool.
10.	For efficient and effective formative evaluations, several (about three) sources and several (about three) **data gathering instruments** should be used.	Digital tool can be the instrument for various reliable data for formative or summative evaluations.
11.	The **creativity and artistic skills** of the designer should be clearly visible in the final product.	Digital tool can heighten the creativity and artistic skills of a designer.
12.	Designers should ask those with an important role in the development and implementation for their early participation in the design activity.	NA
13.	While making an educational design, designers should start from the needs of the learners, rather than from the content-based structure.	NA
14.	Designers should conduct **formative evaluations** themselves.	Digital tool allows designers to conduct formative evaluations on their own.

15.	Successful design is served by the use of step-by-step **schemes and design models**, provided that they have adapted.	Digital tool not only allow adapting but validating the function. It may take the function of a design models as it promotes more of a 3 dimensional approach in designing and may heighten their creativity level.
16.	An essential part of the analysis phase is a consideration of **possible pitfalls and problems** during the design and implementation phases.	Possible pitfalls and problems may be identified with simulations.

2. The Technical Module

In order to examine the outcome of incorporating digital simulation as an e-learning tool to create a blended learning environment, the dynamic learning in terms of knowledge and skills acquired by architecture design students are investigated. The study was conducted within a technical studies module conducted in an undergraduate architecture programme in a Private Institute of Higher Education in Malaysia. Brunton (2006), states that effective integration of sustainability concepts as part of teaching and learning is characterized by full integration of sustainability concepts into the curriculum, student-centered activities and assessments that reward critical thinking and reflective learning, multidisciplinary teaching and learning, teaching that emphasizes that sustainability is an ongoing process without hard and fast answers.

2.1 Sustainability

The module addresses sustainability in depth by addressing the basics; addressing and incorporating natural environment, the sun in analyzing an existing building as a case study. This process is explicitly done in many architectural design projects as an initial exercise but not carried through in the student's individual design. This technical module supplements in a way of direct integration studying sun-shading element of a case study in attempt to instill critical thinking by simulating, evaluating and justifying the functions in order to create a thermally comfortable environment for users. This is a basic attempt to curb internal heat gain to avoid high energy consumption for air-conditioning being the biggest issue of sustainability in tropical countries. By modelling a sun-shading element in Autodesk Revit, the function or the internal condition can be simulated by understanding the principles behind the sun-path in relation to buildings.

2.2 The Case Study Project

The case study project uses learning by doing approach advocating blended learning comprising of (1) Traditional Learning (Lectures and tutorials), (2) Experiential Learning (Field trip), (3) E-learning (Digital simulation), and (4) Informal Learning (reading, research, You Tube, learning from peers, etc.). This approach requires high level of commitment from students to achieve the intended learning outcome. Marquardt and Waddill (2004) believe that learning by doing or action learning can be applied in a variety of ways and settings, both face-to-face and virtually because of its flexibility in learning. They call it a powerful tool as action learning stimulates learning at any level; individual or team. By completing the project in groups, students are expected and intended to learn from each other's learning style to cultivate holistic design thinking in architecture students. The case study starts with formulating groups of students whom then each group proposing a case study followed by a site visit to create experiential learning. Prior to the site visit, students went through lectures and research process to obtain preliminary knowledge through resources such as books, journals, videos, and online archives amongst others. According to Ng and Sujatavani (2010) field trip is a common strategy which exposes students to architecture and the built environment through real-life experiences and integration of field trips into the syllabus enhances the quality and process of learning. During the site visit, students are encouraged to conduct their data collection such as recording temperature, date, time,

interviewing users for satisfaction of their thermal environment and photographing interior and exterior spaces. Subsequently, they interpreted the data collected to analyse the simulation.

2.3 Digital Simulation as e-learning

Siemens and Tittenberger (2009) state that academics need research mind-sets to succeed in their discipline and it is more important when teaching with technology. This e-learning method of using simulation incorporated in this technical module is adaptive type (Littlejohn & Pegler, 2007) of e-learning and content based (Atif, Benlamri, & Berri, 2003), requiring high level of Bloom's Taxonomy to simulate and to decipher the digital simulation thus advocating in acquiring dynamic skills (Aldrich, 2005) which then results in transformational learning which is highly vital in teaching and learning in architecture. Apart from this, using technology for communication through Facebook, Instructional Management System (IMS), you-tube, re-wind and such that higher educational institutions categorising as e-learning platforms were also being used but not measured in this study.

The simulation is based on re-creating effect of actual sun light and shadow of a chosen sun-shading element in a case study according to the annual sun path for tropical climate. E-learning using digital tool for simulation designed for this project requires integration of knowledge and skills acquired through all 4 various learning in this module. Emphasis is given on each learning type to facilitate students to complete the project in a successful level. Each group are given similar attention by tutor and guided through the process of learning. The project encompasses high-level of Bloom's taxonomy; analyze, synthesize, and evaluate the function of a sun-shading device. This simulation project is the researchers' initiative in developing content based knowledge as an e-learning approach and according to Atif et al., (2003) this shift in e-learning to content development based system is recent, nevertheless, significant work have been undertaken to develop e-learning standards and specifications.

The digital tool used for this project was Autodesk Revit, building design software specifically built for Building Information Modeling. This software is included as part of creating, simulating and analyzing the results in the form of visual data in this module and if reversed it has a great potential as a designing tool. A demonstration workshop session and instructional video were provided. Student was not penalized for using other software with the same competencies but required prior approval from the instructor. Using digital tools or simulation enables students to formulate many thoughts as opposed to designing on paper or physical model in a very short time. Testing the functions of a shading device on paper and physical model may take longer time to acquire the skills and the complexity of applying and testing might be a tedious labour intensive work that might not motivate the students to even try. The learning outcome or the project submission is an A3 analysis board graded using the rubric.

3. The Method

The data collection for this study was administered at the completion of the module by obtaining student's feedback using questionnaire. Questionnaire is used as a data collection technique because it enables the researchers to cover an extensive amount of information -from demographic characteristics, to behavioural habits, to opinions or attitudes on a variety of topic - across a large number of people in a limited amount of time. This technique is selected because the study compared students' overall assessment of their dynamic learning by incorporating e-learning approaches achieved in this module.

The questionnaire is obtained from a total of group of 30 volunteers who have completed the simulation project. The questionnaire used a Likert scale of 1 to 5 and was divided into 3 parts: (1) *Overall perception of the project and experiencing Blended Learning* which has 11 questions to investigate more on the different learning methods and the outcome. (2) *Knowledge and skills acquired for critical thinking* which has 14 questions which emphasizes the aim and objective of the module, (3) *Skills for Life-long learning; metacognitive strategies and reflections.* This aimed to find out about the transferrable skills gained by students and how the module impacted on their intent for learning in a dynamic learning environment by instilling a digital simulation. This part has 8 questions which asked about abstraction, relearning, and the application of knowledge to design module in architecture studies. The questionnaire provided data on the overall perception

of students towards the dynamic learning, to examine the outcome of the integrated e-learning method, and to further understand how the developed blended learning is useful and where it is failing. Face and content validity of the instrument were done by two experts in the architectural education field. Statistical Package for the Social Sciences (SPSS) Version 20 software programs was used to analyse the quantitative data. Descriptive statistical analysis was used to determine mean scores, percentage, and standard deviation.

4. Results and Discussion

From the questionnaire conducted, students ranked the following in terms of their understanding of the various dynamic learning of gaining knowledge and skills used in the blended learning techniques to achieve the Learning Outcome of this project. The first and second ranking are both Traditional Learning; the first being tutorial and followed by lecture. The third ranking and fourth are very close to each other and they are Informal Learning using video instructions (E-learning) and site visit, Experiential Learning. The Last two (2) are reading suggested material, Informal Learning and E- Learning workshop of Autodesk Revit sun shading simulation. Architecture students have been explicitly exposed to all the teaching and learning method introduced in this project in their prior semester's learning except simulating. Thus in this module the students were able to learn new skill using a software (Autodesk Revit). Although students found it hard to comprehend the whole project in the beginning, with high level of guidance and informal learning most of the students were able to apply the knowledge gained and skills in achieving a good Learning Outcome. This proves that Architecture students are inquisitive and with guidance could achieve the capability of being a good designer. According to Aldrich (2005) too within the most e-learning focused learning, instructor-supported dynamic learning of using simulation is highly effective.

Recent instructional design theories for project-based or problem-based learning tend to focus on authentic learning tasks that are based on real-life experiences as the driving force for complex learning (Merrill, 2002). According to these theories, authentic learning tasks have many different solutions, are ecologically valid, cannot be mastered in a single session, and pose a very high load on the learner's cognitive system. Consequently, complex learning has little to do with learning separate skills in isolation, but foremost it is dealing with learning to coordinate the separate skills that constitute real-life task performance. The lowest ranking for instructions for e-Learning had only 16.7% disagreeing and 66% agreeing to the statement, "I am able to understand workshop to introduce Autodesk Revit". Thus the students' were able to comprehend all the teaching and learning method but lowest on the E-learning as it is a new method being introduced to them for the first time. The rest of the other learning methods are very familiar to architecture students.

As noticed by the researchers and the data suggest that students cannot comprehend the whole project at one time but were able to understand the timeline and assigned weekly tasks. Kester, Paas & Van Merriënboer (2010), explain that in complex learning the whole is clearly more than the sum of its parts, because it also includes the ability to coordinate the parts. Thus the delivery of the project was highly instructional based as weekly tutorials were highly assisting students in successfully achieving the Learning Outcome and was ranked first for learning method most understood by the students. From the grade distribution for the project was; 64% scored A, 21% scored B, 4.9% scored C while 10.1% scored D and F. Whereas the participants' grade distribution were 80% for A, 10% for C and 3% for F.

The data collected explicitly portrays that students were able to highly understand the new knowledge and skills imposed to be gained in order to complete this project, followed by analysing skills much needed for critical thinking and familiar to Architecture students and explicitly used in Architecture Design Studio. In an open ended question the frequency rate was high for those listing "software" skills and followed by "analysing" to a question that said list the new skills acquired in this module.

The meta-cognitive skills or comprehension of assimilating, abstracting and deducing the data from various sources were challenging to these students. According to Kester et al. (2010) in project based learning effective performance relies on the integration of skills, knowledge and attitudes. Complex knowledge structures are underlying problem solving and reasoning skills and require differentiation by recognizing qualitative

differences among the task characteristics that influence the constituent skills that have to be applied. The most challenging task for the students was acquiring skills to simulate sun-shading using a digital tool. The students found difficulty in relating to knowledge gained in various learning methods and to digitally simulate; such as visualizing 2D sun path introduced in lecture in 3D in Autodesk Revit, gauging the size and scale experienced during site visit in 3D model. Students also found that critically relating the findings to aesthetics of the building fabric daunting but not to an alarming state. These skills will be essential in Architecture Design Studio and as to incorporate nature as part of sustainability initiative. Owen (2007) emphasized that design thinking is in many ways the obverse of scientific thinking. Where the scientist sifts facts to discover patterns and insights, the designer invents new patterns and concepts to address facts and possibilities. In a world with growing problems that desperately need understanding and insight, there is also great need for ideas that can blend that understanding and insight in creative new solutions. Implicit in this notion is the belief that design thinking can make special, valuable contributions to decision making.

The two (2) highest scores for mean comparison based on all statements in this survey are from the reflection component. The table below highlights the mean comparison based on statement for the reflection component. The researchers found that although 90% of the students understood that sun-shading is the basic knowledge to address sustainability in a building only 80% of the student will be able to adopt it in their Architecture Design Studio. 93.3% of the student agreed to the statement that they learnt new skills by attempting this project and had highest frequency for listing software (digital simulation) followed by analytical skills.

Table 2: Mean Comparison based on statements

Statements	Mean
I agree that by creating sun shading in my design I am addressing sustainable architecture	*4.33
I agree that sun-shading is a basic design that can reduce heat gain in building	*4.30
I am able to learn new skills by attempting this project	4.17
I am able to adopt the same procedural experiment in designing sun-shading in my Architecture Design Studio	3.90

Notes: (*) statements for highest mean comparison

5. Conclusion

Project based learning using case study and learning by doing approach creates a dynamic learning for Architecture students. E-learning was carefully selected in this module as a content based use of technology to benefit the teaching and learning and to facilitate in accomplishing the learning outcome. As computer technology is advancing rapidly, it is essential for students to be adoptive and adaptive to the current technology. Dynamic learning skills of adoptive and adaptive capabilities are essential as meta-cognitive capacities in design thinking to be creative. Simultaneously scientific thinking encourages experimental method to create novel designs. In this project, by replicating and supplementing Architecture Design Studio based learning in a Technical Study module, students were able to enhance their critical thinking skills based on scientific approach. Overall it allowed for the development of student's discipline-specific knowledge, gaining new knowledge and skills to simulate using digital tool and enhance their analytical skills. However further studies need to be researched if students do apply their new gained knowledge and skills in their Architecture Design Studio projects. The insights of whether they do or don't would provide a valuable understanding of teaching and learning in an undergraduate architecture programme.

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