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Digital Design Approach in Architectural Studio Project. Case Study: University of Malaya (UM)**Mohd Farizuda Rosli¹, Asrul Sani Razak¹, Nooradzman Abbas Ahmad¹, Nila Keumala¹, Mohammed H. Al Sabahi¹**¹Department of Architecture, Faculty of Built Environment, University of Malay (UM), Kuala Lumpur

Email: farizuda@um.edu.my

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Abstract

In the past, while little construction documents exists, it is known that drawing and physical models are used to illustrate the intended building to be build. As the progress of computer started to kick-in in the early 1980's, architects adopt Computer-Aided Design (CAD) to automate their orthographic drawings which was before expressed manually using T-squares and pencils. Currently, the practice of architectural curriculum in Malaysia outlined by the Board of Architect of Malaysia is to teach the architecture students to use manual drawing in their first year of study and continues with the use of CAD in the following years. In the current development of computer technology, Building Information Modelling (BIM) seems to be slowly replacing the use of CAD in architectural education and practice. This pose a question whether these advancement of computer does help the architecture students for their design studio project. The aim of this study is to investigate the perception and effect of the use of computer on the architecture students' performance. The study looks upon the perception of academicians in Malaysia's Public Universities (PU) on the development of computer and investigates the effect of the use of computer as a design tools on the performance of architecture students. Based on a series of interviews with six head of department of architecture schools and one lecturer-architect, the study investigates these academicians' perception towards the development of BIM to the architectural curriculum. Next, using a case study from the architecture school of University of Malaya, based on a survey, the study divides the students into three category of design tool used by the students to produce their design product – manual, computer, and hybrid. The study compares each design tools with each student's design studio grade. The study also compares the cost effectiveness of the usage for each design tools. From the interviews, all HODs from the interviews agrees that the development of computer and BIM is beneficial and inevitable to the architectural curriculum in Malaysia. From the survey, hybrid design tool – mixed of computer and manual drawings, are the better design tool in terms of cost effectiveness and students grades.

Keywords: architecture design studio, design tools, Computer-Aided Design (CAD), Building Information Modelling (BIM)

Introduction

In the past, before the advancement of virtual design tools and software, architect design are prepared manually by hand through the aid of physical design tools e.g. pencils, T-square, set squares, rulers. As building design progress to become more complex throughout the ages, technological advancement has opened a path for architect to project their ideas using computer instead of paper. As the progress of

computer started to kick-in in the early 1980's, Computer-Aided Design (CAD) was used by architects to automate their orthographic drawings which before was expressed manually using hand drawings. CAD quickly becomes an important tool for architects as it removes their limitation with manual drafting. The speed and flexibility that CAD provides has caused manual drafting to become obsolete in our current architecture practice.

In architectural education, manual drafting is still been taught among the architecture students especially in their early year of study. This is to serve as a basis for them before they shift into using CAD. The knowledge of designing using physical design tool has become a prerequisite for architecture students. This is to train them to be able to communicate their thinking and intention through the tangible tools as well as to train the students to not to rely solely on the virtual design tool.

Manual Drafting and CAD

In the past, the need for extensive construction documents are small as buildings were constructed using few drawings and a pattern book of carpentry and masonry details. Only by the eighteenth century, 'pretty pictures' for presentation and communication purposes were done by water colouring the drawings on vellum as shown by Beaux-Arts architectural drawings (Levy, 2012).

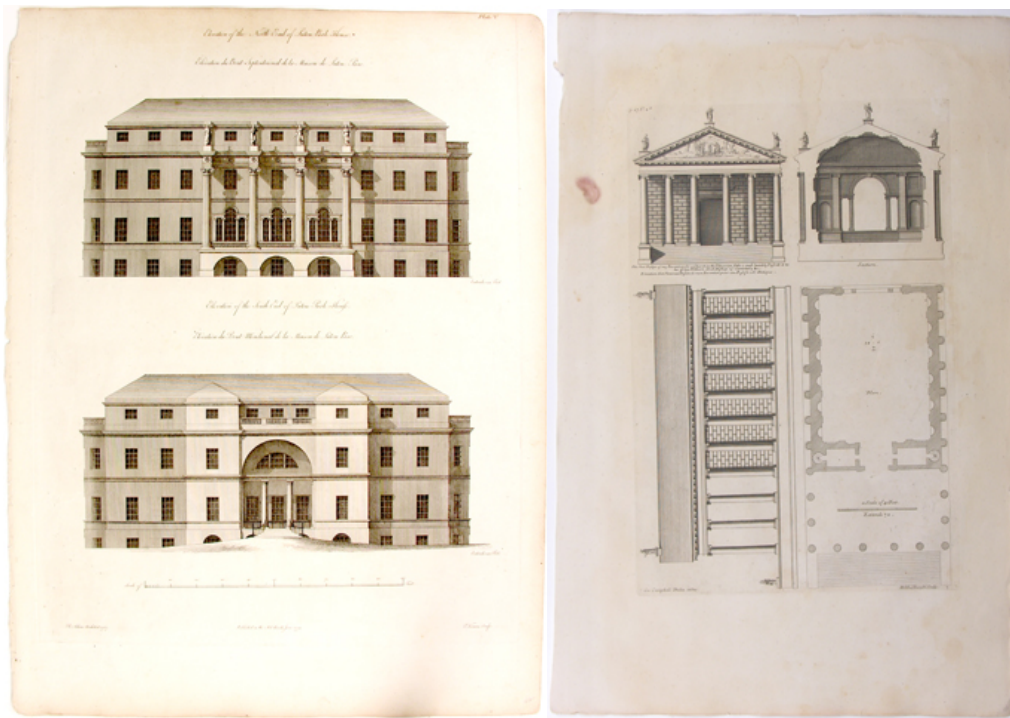


Figure 1: Examples of 18th century Beaux-Arts architectural drawings

Source: http://www.beauxartsart.com/m_architectural.html

In the early 1980's, architects started to use CAD to automate their drawings which was before expressed manually (ibid). With this advancement in computer, different building information which was represented by 2D drawings, quantities, perspectives, costs and engineering calculations was able to be produced through separate computer software.

Even though the advancement of computer increases drawing production capabilities, it does not automatically develop a proper understanding for the CAD operators towards the knowledge and technicalities of drafting e.g. projections, layout, related views and positions, line weight, density/depth, etc. (McLaren, 2007). McLaren (2007) also stated that there are an agreement between industry, teachers, and school students of the value in learning how to construct and draft technical drawings using the physical drawing boards instruments. There was near consensus among all sample groups that the practice of using manual drawing before advancing to the use of CAD was a preferred route of progression. This is crucial in order to develop better understanding of the underpinning

conventions, geometry and theories associated to technical drawing (ibid). Raudebaugh and Robert A. (1996) in their paper entitled 'Manual Drafting: A Skill for the 21st Century?' recommend teaching drawing in the context of the design process, including all types of drawing, and focusing on freehand techniques for ideation and communication.

Building Information Modelling (BIM)

From their first meeting on the 24th July 2013, the Steering Committee of Building Information Modelling Malaysia has define BIM as 'modelling technology and associated set of processes to produce, communicate and analyse digital information models for construction life-cycle' (CIDB Malaysia, 2014). BIM is a new way of working with a set of new technology.

Since the financial crash of 2008, the architectural practice in UK seems to be struggling in finding the right candidates for some positions in the firms. 65% of respondents in RIBA Appointments Skills Survey 2014 reported difficulty in finding the candidates with suitable experience and skills. The top five scoring skill and knowledge areas that the report suggested as the desired skill and knowledge includes: Building Regulations and Standards, Planning System, Design and Specification, the RIBA Plan of Work, and BIM (Building Information Modelling) (RIBA Enterprises Ltd, 2015).

As construction projects becomes more and more complex, management of information becomes a crucial factor for a success of a project execution. The information created using BIM could be reused, updated, redesigned and analysed by having the 3D data rich model in a single file instead of using separate files that contains separate or duplication of information in them. A major shift in information and communication technology (ICT) has been happening in the construction industry globally by the introduction of BIM. While the term BIM has been a while in manufacturing and engineering industries, it is now beginning to mark an impact in the building industry globally, including Malaysia.

BIM in Malaysia

Although BIM softwares were available in Malaysia since 2002, it is only by the year 2010 that the drive of BIM started to kick-in in Malaysia (Ahmad Tarmizi Haron, 2012). The first project that was reported to be using BIM in Malaysia was the National Cancer Institute Project (Ahmad Tarmizi et al., 2012; CREAM, 2014).

The focus of BIM in Malaysia at the current stage is to develop the competency of the AEC industry from 2D Line Based Draughting (2D LBD) into 3D Object Based Modelling (3D OBM). This stage is what Succar (2009) called as the BIM stage 1.

In 2014, the Construction Research Institute of Malaysia (CREAM) came out with a report entitled 'Issues and Challenges in Implementing Building Information Modelling (BIM) for SME's in The Construction Industry' which stated that the Malaysian government saw BIM as an important tool in managing their properties in the future. Due to this fact, the Malaysian government are targeting to implement BIM by the year 2016. (CREAM, 2014)

Architectural Education in Malaysia

The structure of architectural education program outside of Malaysia that will reward an individual with the Board of Malaysian Architect's (LAM) part 1 and part 2 recognition would normally be outlined either as a 5 years program, a 3 + 2 years program – first 3 years for Bachelor of Science in Architecture (part 1) and another 2 years for Master of Architecture (part 2); or a 4 + 1 year program – first 4 years for Bachelor of Science in Architecture (part 1) and a year for Master of Architecture (part 2) (Kementerian Pengajian Tinggi Malaysia, 2011).

The current practice that is common in the architectural education is using the 3 + 2 years program. This is following the Bologna Accord which was set by the European Higher Education Area in 1999 (European University Association Website). This 3 + 2 years approach is considered flexible,

compatible, comparable and suits with globalization system (Kementerian Pengajian Tinggi Malaysia, 2011).

The current practice in Malaysia's public universities are following the same 3 + 2 years of program – first 3 years for Bachelor of Science in Architecture (part 1) and another 2 years for Bachelor / Master of Architecture (part 2). However, only three out of the seven public universities in Malaysia that is currently offering Master in Architecture degree after the 3 + 2 years of study i.e. University Teknologi Malaysia, University Teknologi Mara and University of Malaya. The rest of the universities are still offering Bachelor in Architecture degree to students although in the report 'Hala Tuju Pendidikan Seni Bina di Malaysia' (Architectural Education's direction in Malaysia) by the Ministry of Higher Education Malaysia (2011), it was suggested that all architectural education in the public universities in Malaysia should convert their part 2 program from Bachelor to Master degree.

In Malaysia, the management for the architectural department within a university is either under the faculty of built environment, faculty/school of design or faculty of engineering. Management of the architectural programme in Malaysian public universities are normally been put under either the Head of Department, Head / Chairman of Programme or Head of Studies.

Table 1: List of faculties that offer Architectural Programme for Malaysia's public universities

No	Public University	Faculty that offers Architectural Programme	Part 1 Architecture	Part 2 Architecture
1	University Teknologi Malaysia (UTM)	Fakulti Alam Bina	Bachelor of Science in Architecture	Master of Architecture
2	University Teknologi MARA (UiTM)	Fakulti Seni Bina, Perancangan dan Ukur	Bachelor of Science in Architecture	Master of Architecture
3	University Sains Malaysia (USM)	Pusat Pengajian Perumahan, Bangunan dan Perancangan	Bachelor of Science (Housing, Building and Planning) (Hons)	Bachelor of Architecture
4	University Malaya (UM)	Fakulti Alam Bina (Faculty of Built Environment)	Bachelor of Science in Architecture	Master of Architecture
5	University Islam Antarabangsa Malaysia (UIAM)	Kuliyah Seni Bina dan Reka Bentuk Alam Sekitar	Bachelor of Science in Architectural Studies	Bachelor of Architecture
6	University Putra Malaysia (UPM)	Fakulti Reka Bentuk and Seni Bina	Bachelor of Science in Architecture	Bachelor of Architecture
7	University Kebangsaan Malaysia (UKM)	Fakulti Kejuruteraan dan Alam Bina	Bachelor of Science in Architecture	Bachelor of Architecture

All architectural curriculum around the world centres around the architectural design subject. The accreditation body have set that 50% of the architectural curriculum is dedicated to architectural design subject (Kementerian Pengajian Tinggi Malaysia, 2011). This shows the importance of architectural design subject in order to shape the architecture students to integrate their skills and knowledge of the many aspects of architectural design components.

Generally, architectural curriculum consists of five core components:

- i. Architectural Design
- ii. Socio-Cultural Context
- iii. Technology and the Built Environment
- iv. Communication
- v. Law and Management

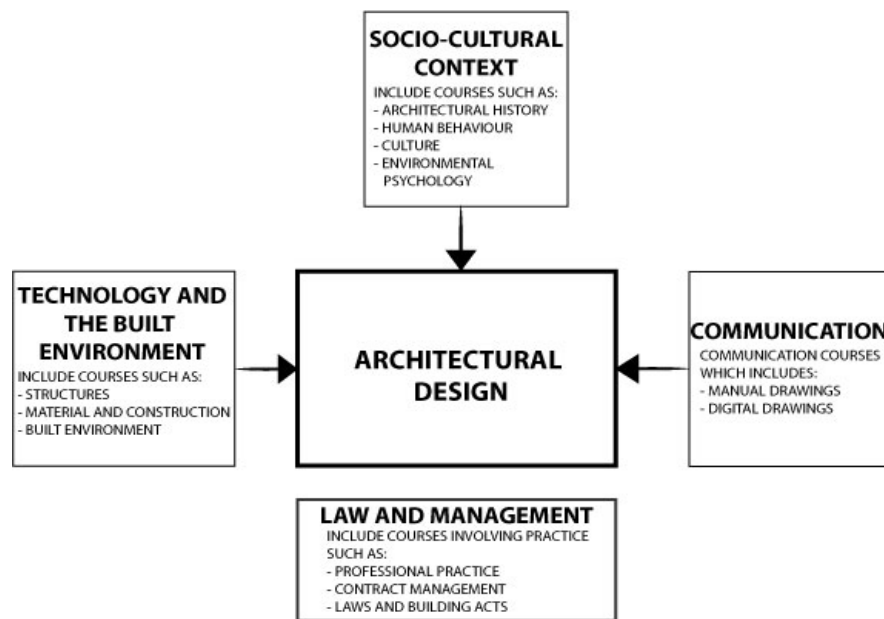


Figure 1: Five core components of Architectural Education in Malaysia
(Adapted from Kementerian Pengajian Tinggi Malaysia, 2011)

The architectural education centres around the architectural design where knowledge from the other three core components – Socio-Cultural context, Technology and the Built Environment, and Communication; will be integrated and used to enhance the architectural design project of the student (Figure 1). The Law and Management component does not directly relates to the Architectural Design component but it serves as a management and administration aspect of an architectural practice that architects should have at the back of their mind e.g. matters involving authorities, building approval submission, building laws and code of conduct, etc.

Architecture Department in University of Malaya

Started as a small unit, the architecture program at UM was established in the year 1995 in the Faculty of Engineering. Six years later, in 2001, a new faculty, the Faculty of Built Environment was established. The faculty consist of four departments; Department of Architecture, Department of Estate Management, Department of Building Surveying and Department of Quantity Surveying. The Faculty of Built Environment introduced another department called the Department of Urban Planning in 2012 and a year later, the entire Faculty relocated to a new building which was equipped with the latest technologies and tools to support the teaching of these courses. The teaching of CAD is mainly taught during the second year level in the Architecture Program. The CAD course consist of two parts; the first part is for 2D drafting while the second part is for 3D modelling and animation.

Aim and Objectives

With the advancement of computer, it seems inevitable that future architects must possess the right knowledge and operation skill using computer to design the future building.

The aim of this study is to investigate the effect of computer usage as a design tool in architectural studies in Malaysia. This study will answer that aim by tackling two objectives.

First objective of this study is to investigate the perception of the academicians in seven public universities (PU) in Malaysia on the progress of computer in the architectural industry. This is to gauge the perception of the academicians in the architectural community on the development of computer towards the architectural education. Majority of the academicians that involve in this study are the Head of Architecture Department (HOAD) for his/her PU.

The interview questions will embark directly towards development of Building Information Modelling (BIM). This is because BIM is seen as the latest development in computer technology in the Architecture, Engineering and Construction (AEC) industry worldwide including Malaysia (Pittard, 2012; Waterhouse, 2013). BIM is also seen as the future replacement for CAD. This BIM movement in Malaysia is evident with the first international BIM day that was held in Kuala Lumpur in 2014 (CIDB Malaysia, 2014).

Next, this study investigates the difference of using two different design tool for an architectural project – manual and computer. This investigation is made by taking a group of final year part 1 architecture students in University of Malaya as a case study. The students are divided into three category based on their choice of design tool to produce their architectural project – manual, computer, or hybrid.

By having students as a case study, few perimeters are controlled and comparison of the two design tools can be done. The students are designing similar building typology using similar design brief. Some of the students are using full manual tools to design their building, some are using full computer, and some are using both. The exact percentage of these three groups will be discussed further in this paper. By having similar project with similar project brief and requirements, the study could compare the difference of using manual and computer towards the project.

At the end of the project, each students were given individual grade for their project. By measuring the grade and the design tool used by each students, the study can identify which design tools contributes to the better grade of the students.

A Brief Review On ‘Participatory Design’ And ‘Service Design’

Participatory Design (PD) can be defined as new approach towards computer systems design in which people destined to use the system play a critical role in designing it (Schuler and Namioka, 1993). The first innovation concept of PD was used in 1990 by Paul Czyzewski, Jeff Johnson, and Eric Roberts in the Conference of Participatory Design proceedings expressed that computerization through advancement tools are more helpful to the workers in doing their jobs. From their expert view of point, they highlighted that;

‘Assume the workers are in best position in determining to improve their work and their work life. So, the traditional designer-user relationship will be enhance, which improve their knowledge about what they do and what they need – become as designers as technical consultants’

‘User perception of technology will have their view on importance of computer technology and feeling about the system rather than consider it as workplace, and admire it as process rather than as products’.

Since there, the computer-based systems become more and more integral parts of people's work lives. Many design professionals and managers alike are realizing that the skills and experiences of workers need to be present in the design and organizational implementation of computer systems and the work they support. Increasing on PD research develop more on understanding of relations between work and technology and the tools and techniques applied, are being integrated into design professional's resources for action.

Continuously, the definition of Service Design (SD) can be several, namely the work of specifying an idea about a new service in drawings and specifications (Norling et al, 1992); a number of ways from a narrow view of being concerned with the 'idea generation' portion of the new services design process (Edvardson et al, 2000) to the whole process of service development (Sundbo, 1998); and so on. Nevertheless, the originated service design process is from service organization that deliver a service after integrating (or outsourcing) investments in numerous assets, processes, people and materials (Ang, 2017; Hua, 2016a; Hua, 2016b; Goldstein et al, 2002). However, service components are combinations of processes, people skills, and materials that must be appropriately integrated to result in the 'planned' or 'designed' service. Hence, service design can be express as an appropriate mix of physical and non-physical components. In other words, the service design concept can be expanding more as several important points, namely (Johnston and Clark, 2001);

- i. Service operation, the way in which the service is delivered;
- ii. Service experience; the customer's direct experience of the service;
- iii. Service outcome; the benefits and results of the service for the customer;
- iv. Value of the service; the benefits the customer perceives as inherent in the service weighted against the cost of the service.

So, the PD and SD will be applied into university perspective as one of the educational program in which system technology become more important tools for students in applied into working phase.

Methodology of Study

Interview

For the first part of the study, a qualitative method of data collection were done through seven interviews – six interviews with the HOAD and one interview with a part time lecturer-architect; from seven PUs in Malaysia. The interviews were recorded using a voice recorder and were transcribed by the author. The data that were obtained from the interviews includes – the opinion of the HODs regarding the development of BIM in Malaysia, the impact of BIM towards the architectural students and the suggestion for BIM application to the architectural education in Malaysia.

In this study, the name of the interviewees and their respective university are not revealed. This is to avoid bias from the reader as the reader might like or dislike the interviewees or any particular university. The main intention of making the interviewees and the universities as anonymous is to focus the discussion on the content of the interviews rather than the interviewee or the university of the interviewee. However, the position of each interviewees will be spelled out to give credential and reference for his/her statements. The detail of the interviewees is tabled out in table 2.

Table 2: List of interviewees details.

No	Public University	Interviewee	Interviewee's Position in his/her Organization
1	PU1	i1	Head of Architecture Department
2	PU2	i2	Part time lecturer; Practicing & Principle Architect
3	PU3	i3	Head of Architecture Department
4	PU4	i4	Head of Architecture Department

5	PU5	i5	The acting Head of Architecture Department (At the time of interview)
6	PU6	i6	Head of Architecture Department
7	PU7	i7	Head of Architecture Department

The interview consisted of semi-structured questions designed to allow the respondents to express their experience and opinion freely during the interview session. Each interview session lasted between 23 – 72 minutes of time duration. The questions for the interview were based on previous literature review which focuses on BIM in Malaysia, role of architect with BIM, and architecture education on BIM.

Seven interviews were considered enough for this study as there were only seven public universities in Malaysia that offers architectural course. According to Ryan and Bernard (2006), the decision to stop interviewing may happen when the number of interviews done already gives a sense of data saturation with emerging pattern or theme from the interviewees. There are consensus among the interviewees on few theme, especially on the computer development that will be discussed later in this paper.

Design Tool Usage Survey

The second part of this study consists of a survey questionnaire. This survey contains question on the average time spent by the students for design process, time spent on final draft, time taken to learn the basic of selected design tools, number of drawing produced, cost of preparation, production, and grade obtained. This data will be collected through the use of offline survey questionnaires that was handled to the targeted architecture students.

The variable for the survey are as follow:

- i. Manipulated Variable: Selected Design Tools (virtual/physical)
- ii. Responding Variable: Performance of architecture students
- iii. Constant Variable: Design Project

Three categories of students will be identified through this survey. Students who fully utilize the virtual design tools are identified as Computer user, those who fully used physical design tools will be categorized as Manual user and those who combine both tools will be categorized as Hybrid user.

Result and Discussion

Interview

For this part of the paper, this study will discuss the findings from the seven interviews. An overarching theme of these interviews are the current development of BIM in Malaysia and the effects it could have to the architectural education in Malaysia. Although not all findings in these interviews are relevant to this study, some of the findings are relevant to the discussion of this study. Thus, only a portion of the interviews' findings will be inserted and discussed in this paper.

Overall, the interviewees show a common understanding of BIM. Mainly all interviewees knew that BIM is a technology which involves 3D visualization, the information are embedded in the 3D, drawing generations are easier and faster, and collaboration with other AEC professionals are easier with BIM.

"... (BIM) it's very beneficial because it can cut short the time of getting other thing. Because it's quite a comprehensive one (tools). Maybe for architecture students for example, they (may/can) design and they specify the building material, construction system, something like that, so straight away they could come out with, for example, pricing, schedules and everything. We can cut short the time. " - i2

"(BIM is) Good management in Building design - Database of building that can be use to generate cost, calculation, schedules, etc." - i6

"BIM is an integrated approach of designing. And then after you provide the detailing, costing and eventually, even now I think embedded in BIM software also you can simulate the building performance for thermal comfort, natural lighting, acoustic performance and so forth. It's integrated from architecture and engineering aspects of design and eventually will lead to costing. So, it makes life easier when you go to construction when everything have been resolved during the design stage. You will minimize of course, variation orders, and will speed up the works because everything have been resolved earlier on. No more clashes between architecture and engineering aspect." - i4

All interviewees also see that BIM is gaining a lot of attention in Malaysia and the Malaysian construction industry are moving towards it. The architects, especially the young ones would love to get their hand on BIM. The interviewees generally see that BIM will be welcomed by the architects as it will improve their design of a building due to its efficiency and time saving. In fact, majority of the interviewees see that the architects could be more than just designer by leveraging themselves with this new technology – some even suggested that architects could be the master builder again.

"I think most of the architects like BIM."

"Of course it'll improve it. ...once you work in 3D you can... already visualize how your building will look (like) when it's completed." - i2

"I think generally architects welcomed it. They know it'll make their life easier in fact." - i1

(When been asked about architect's reaction to BIM) "...Separated into three types: Leaders, or fast adopters, and then 'The wait and see', and then the reluctant ones." - i5

"Well, we'll expect that architects, the older generation of architects might be a bit sceptical but the young ones, I think would look at BIM as an opportunity" - i7

"I don't know what (the architects) are going to be in the future. Before renaissance, there is no terminology called architect, they call (it) master builders. Master builder is somebody who knows (how) to do everything. Construction - engineers, cost - quantity surveyor, managing project - project manager. If using BIM, maybe the architect (would) be possible to do that, even the architect (could also) become the contractor. I think they can be everything." - i6

These reactions show that the academicians – the HOADs, involves in the interviews view the current development of computer software to assist the design of a building as something positive.

BIM in Architectural Education

The studio design is the core subject of an architectural education among the five core components outlined by the Kementerian Pengajian Tinggi Malaysia (Ministry of Higher Education Malaysia) (2011). When the interviewees were asked about a possible new pedagogy for BIM implementation in the design studio, all of them suggested that BIM subject should be taught as a separate subject and to be implemented in the studio by the students themselves. This is due to the fact that the design studio is meant solely for design and BIM is seen as one of the tool for design – a mean to an end. Forcing students to use BIM as a mandatory for design may benefit them – especially the more ‘computer savvy’ type of students, but it would also create a disadvantage to the more conventional -manual

drawings type of students. This reason, as pointed out by one of the interviewees is why BIM should be taught as a separate subject.

Teach BIM in a different subject - separate subject but integrated with studio program. "...because if you try to put it (BIM) directly (in studio program) and tell them that they have to use it and try to maybe teach them that within the studio, then the studio aspect, the design aspect is going to overwhelm them. And then, the technology part, the BIM part is going to be put aside." - i5

"The teaching of the subject should always be separated from the studio, but when it comes to the implementation of the learning, it must be in the studio." - i6

"Maybe one project that they have to use BIM software (as an exercise). But again, we have to approach CAAEM whether this kind of teaching is appropriate or not that to them you will give a disadvantage to the students who don't have the skills to master BIM. So, we can't really impose on that. But hopefully on part two students, then they should have experience using BIM software already." - i4

"Have a test run of BIM software (Revit) as an elective subject (optional subject). After one or two semester, review the subject again and look if it could be incorporated in to design studio program or not." - i3

These findings from the interviews show that eventhough the academicians from the interviews are positive about the current development of computer technology in the architectural industry, they still believes that the usage of computers as design tools should be up to the students. They believed that the students should be given freedom to explore their design tools for their architecture studio work project. Limiting or imposing any particular design tools as the only tools to be used will hinder the exploration of students. It might also create a disadvantage to the students who might not have the proper understanding of the given tools as mentioned by one of the interviewees.

Design Tools Survey

With the interviews findings, the study embarks on the more objective side of this study. Given the positive perception of the HOADs on the development of computer, it poses a question, does the computer really provides a necessary and beneficial assistant to the architecture students in doing their design project?

This section of the paper will discuss about the findings from the survey of the design tools usage – manual, computer and hybrid.

A total of 35 year 3 architecture students from University of Malaya participated in the survey. They were required to fill in the survey form based on their design project from previous semester (year 2, session 2013/2014, semester 2). The said project is to design a library or community clinic in Bandung, Indonesia. The site is located on a hillside. Students are given freedom by their lecturers to use any design tools to present their design. This enable a comparative study to be performed to determine the performance of each design tools. The following are the breakout of 35 architecture students who undertook the survey based on their design tool:

- a. 28.6% (10/35) only use virtual design tools, classified as computer user.
- b. 28.6% (10/35) only use physical design tools, classified as manual user.
- c. 42.9% (15/35) use both virtual & physical design tools, classified as hybrid user.

An even number of students use Computer and Manual design, while majority are using Hybrid method by combining both physical and virtual design tools.

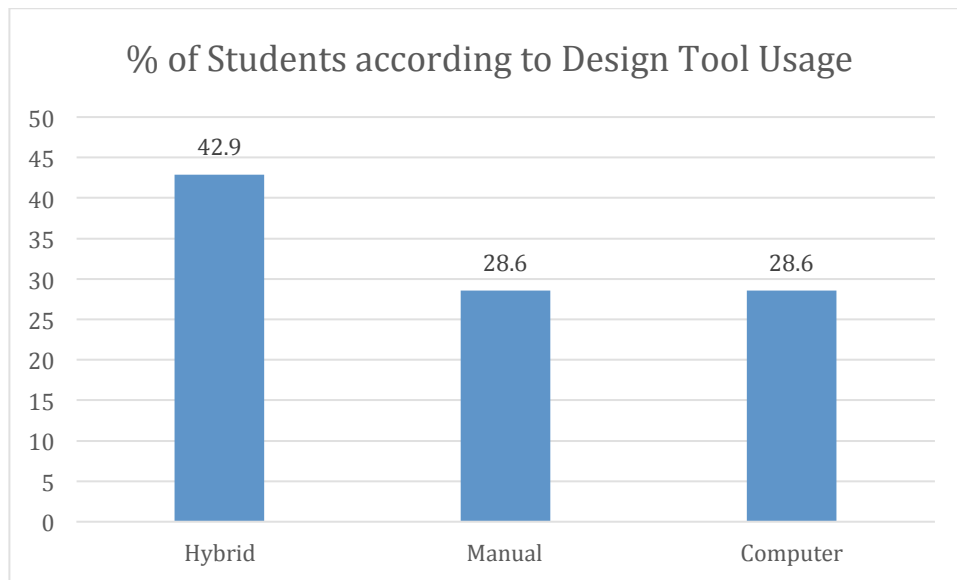


Chart 1: Percentage of students according to the design tool used

In the end of design project, it is up to the lecturers to evaluate the students work. Students will treat the grade given by lecturers as a marker for their current performance.

	Computer	Manual	Hybrid
Grades	B /2.8	B- /2.5	B+ /3.6
A	0	0	1
A-	1	1	2
B+	2	0	4
B	2	3	6
B-	4	5	2
C	1	1	0
Discrepancy	+1.1	+1	+0.5
Aim	0.6	1.4	0.8

Hybrid user earn the highest grade from the lecturers, having the only A, most A-, B+ and B from the entire studio. Manual user on average earn B-

Discrepancy is student's grading of their own work. Every +1 indicates the student expectation of a +1 grade higher. The closer the value to 0, the more satisfied the student is of their given grade. From the table, Hybrid user are the most satisfied with their grade while Computer and Manual user think they deserve a grade higher for their works.

Aim is the student targeted achievement before starting the project. The closer the value to 0, the closer the students achieved for their end product. The value is gauged by comparing the students' initial grade aimed and final grade they give themselves. From the table, Computer user achieved the most while Manual users' end product does not achieved their initial target.

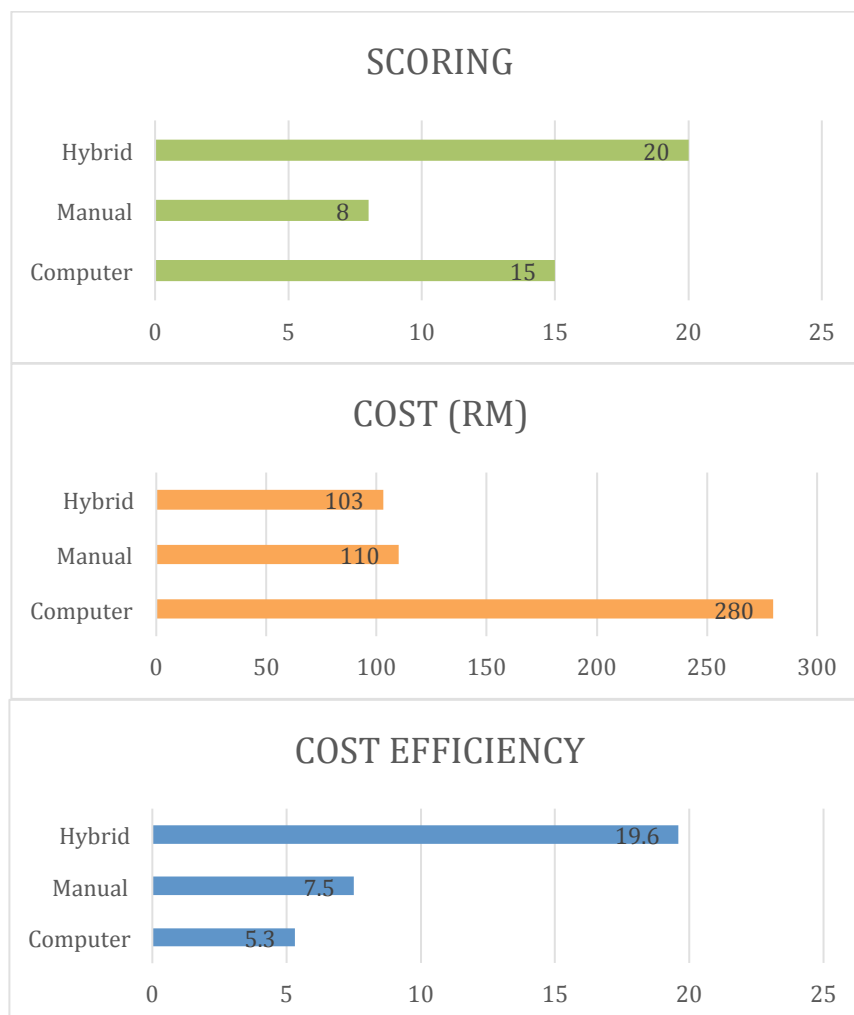
The following is the post final presentation measurements of the total completion rate of presentation board and the total cost spent on it. Completion (%) rate combine the completion of key drawing (100%) and rendering (100%) resulting a total of 200%.

	Computer	Manual	Hybrid
A1 produced	9	8	8
Completion %	160	112.5	143
200%	5	0	3
150%	2	1	6

125%	1	5	3
100%	1	2	2
75%	1	2	1
Cost (RM)	280	110	103
< 50	0	1	2
50 - 150	1	4	6
151 - 250	3	3	5
251 - 350	2	1	1
>350	4	1	1

On average, computer user produce 1 more A1 while having the most completion rate with majority of the user fully completed their drawings and rendering. Hybrid user mostly completed the key drawings and rendered half of it. Manual user only managed to complete key drawings in time and render a few drawings. No manual user are able to fully finish both drawings and rendering.

In term of cost, computer user require the highest funding for their presentation board and the highest amount recorded for an individual is RM 500. The lowest cost goes to hybrid user followed by manual user who spent slightly higher than them.



Manual user to spend slightly higher than Hybrid user due to more cost spend on model and material. Since they have the ability to present their design on exotic presentation board (brown board, black paper, tracing paper, composite paper, etc.) the said material cannot be put inside printing machine for Hybrid and Computer user, therefore only Manual user can use them as a presentation board (which are more costly than standard A1 paper).

Even though computer user has the second highest grade score and the highest completion rate, they suffer from very high production cost which is even more than Hybrid and Manual combined. Average printing cost for one coloured A1 paper is RM 25, combine this with their highest completion rate produce a very high printing cost resulting in low cost efficiency. This is actually untrue in architecture firm but since the scope is architecture students, finance might be an issue for them.

Hybrid user has the lowest production cost. Justified by the fact that they render their drawing manually, they only need to print monochrome A1 paper averaging RM 5. Having the lowest cost and highest resultant grade made Hybrid user superior compared to Manual and Computer user.

Conclusion

Based on the interview study, all academicians that involves in this study agree that computer interventions is a positive development for the architectural education and to the students. Looking at the progress and predominant dependencies of computers in today's world, it's not a surprise to hear that all interviewees saw that this virtual development in architectural practice and education as inevitable. BIM is agreed by everyone as a positive and unavoidable replacement to the current CAD system.

From the survey data obtained, we can conclude that each design methods has their own perks, focus, advantages and disadvantages.

Computer user (virtual design tool) have the best design convention, being able to complete more, produce more, and present better. Even though they tend to be high achiever, they still earn less grade compared to hybrid user. They also has the disadvantage of high production cost.

Manual user (physical design tool) is somewhat an underachiever compared to other user. They obtain the least average grade, and low completion rate. Absence of aid from virtual design tools and total reliance on human force may be the cause of this. However, they have the most room for creativity in terms of model-making and presentation board since they are not bound by the restrictions of virtual design tools.

Hybrid user (virtual and physical design tool) tend to stay between computer and manual user in terms of design aspect, completion rate and presentation. This does not stop them from earning the highest average grade with lowest production cost, leading to most hybrid user to be very satisfied of their final grade. The success may be because they combine both physical and virtual design tools, taking the advantages of each design tools and having them negate each other weaknesses.

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