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This paper focuses on transforming the functionality of classrooms through the utilization of AR to develop adaptive multi-functional architecture classrooms. Literature confirms that various AR techniques have been applied in educational centres, however less research has been conducted in creation of adaptive learning spaces namely architecture classrooms. This study aims to indicate the constraints of current architecture classrooms in private Malaysian universities, moreover, the features of mono-functional and multi-functional classrooms which are discussed and analysed to highlight the potential towards the relevance of AR application in architecture classroom spaces. Case studies that incorporate particular software and hardware requirements are reviewed in order to frame a transparent picture in supporting the theory of creating adaptive educational environments through an exploratory mixed method strategy. An overall statement is made by respondents that space enhancement and technology integration that can support them as educators in being more creative. In other words, it can provide a better use of space, by having suitable facilities. Findings review Suitable AR Features in Architecture, and point out the flexibility of AR in space as one of its characteristics. A variety of compatible software were mentioned and interviewees agreed that an Adaptive AR system can be set up to create the required items related to particular functions such as workshops, seminars, drawing, history class, design illustration, and design communication, etc.
Development of Adaptive Architecture Classrooms through the Application of Augmented Reality in Private Universities of Malaysia

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Abstract: This paper scrutinizes the circumstances of the application of Augmented Reality (AR) technology to enhance the adaptability of architecture classrooms in private Malaysian university classrooms. This study aims to indicate the constraints of mono-functional classrooms in comparison to the potentials of multi-functional classrooms derived from AR application through an exploratory mixed method strategy. This paper expects to contribute towards recognition of suitable AR techniques which can be applied in the development of Adaptive-AR-Classroom-Systems (AARCS) in architecture classrooms. The findings, derived from the analysis, show current classrooms have limited functional spaces, and concludes that AR application can be used in design classrooms to provide variety of visuals and virtual objects that are required in conducting architecture projects in higher educational centres.

Keywords: Design Activity, Space Enhancement, Design Education, Architectural Design Augmented Reality.

1. Introduction

Over time, occupants often want to change the functional space of a room to accommodate new requirements. Likewise, with view to the educational environments, the allocated tasks and requirements of educators and students vary based on teaching and learning needs. In this regard, current educational spaces are not flexible enough to provide a variety of activities. The current educational spaces do not embody sufficient potential to be easily adapted for a range of transformable learning activities and courses (O’Neill, 2009). Therefore, the importance of designing classrooms and educational centres has come to educators’ attention when preparing sufficient space for limited functional spaces. Recent studies indicate that building transformation looks to provide versatile characteristics to mono-functional spaces, such as offices, to improve the functionality of the existing building (Romey, 2009). Creating collaborative learning environment is one of the growing importance fields, that studies on enhancement of facilities and learning environment, sustain teaching resources (Berglund et al, 2006).
According to (Niroumand, 2012) studies, the allocated functions for modern architecture are divided into two terms to cope with human multiplicity; primarily the mono-functional space which is type of space that is only suitable for a particular function or activity. Secondly, multi-functional space, which is an adaptive space in terms of design and facility, it can also support multiple activities in the same place (Imrie, 1998). In this paper, the focus is on the issues of architectural design, namely the functionalities and space role in architecture classrooms in higher educational centres.

The primary objective of this research is to study features of current architectural classrooms with a view to functionality of space. Also this research aims to review the benefits of AR appliance in today’s educational activities used in architectural classrooms. Identification of suitable techniques of AR for development of adaptive architecture classroom is accordingly the ultimate objective aim of this paper.

**Rationales to develop Malaysian higher education centres**

In 2004 the former Prime Minister Abdullah Badawi, in his opening speech of the Malaysian Education Summit, stated that development of education is the priority objective, to be aided by an IT revolution in Malaysian universities. Thus, Malaysian universities have been under strong pressure by the government to improve the quality of education (Olanrewaju, 2011). According to the recent Malaysian Educational Plan 10 MP (2011-2015), universities are expected to contribute significantly to the national future Vision 2020 of transforming Malaysia into a first world country. The government also reduced the amount of direct control over universities (Olanrewaju, 2011).

There is a need to promote an integration of ICT into universities and to develop a more ‘intelligent’ approach toward education (Gupta, 2008). This paper refers to significance of Malaysian universities development with a view to the Vision 2020. The application of the most recent advancement of technology, namely AR, is an IT approach toward enhancement of educational centres functionality.

**2. Functionality in Today’s Architecture Classroom**

As higher education comes to terms with a new generation of students and changing technologies, space design is a significantly fundamental issue (Steelcase, 2011). A university’s role of information and knowledge delivery should consider that IT has drastically changed the education environment (Ismail, 2008). The respective changes have had a considerable impact on the types of functions and structures within university classrooms (Gayle et al., 2011). This study denotes that current educational spaces are not flexible enough to allow a variety of activities (O’Neill, 2009). Thus, this paper aims to explore ways to apply the suitable applications in IT to combine the virtual environments with actual environments called Augmented Reality (AR). In this regard, Gayle et al. (2011) suggests that every university that desires to be competitive in the 21st century has to consider IT applications as the most necessary tools in knowledge delivery. AR interacts with educational spaces by creating full scale sets of virtual furniture and virtual
space dividers enabling users to interact with a variety of virtual spaces to enhance the functionality of the spaces.

**The Design Layout of the Classrooms**

Limited space in higher education environments with a view to the various needs of a new generation of students in learning, has led designers and researchers to consider the redesign of classrooms. The following is a response to the need for interactive learning environments through technology application.

**Table 1: The problem in today’s classroom**

According to the review of recent scholarly studies, it is inferred that most universities in Malaysia need to implement access to IT in the classroom (Ismail et al. 2008). According to Vicziany and Puteh (2004), Malaysian universities are still behind in IT usage in educational centres. AR applications within educational spaces can improve space functionality in higher education. ‘Adaptability and re-configurability’ are directly linked to the quality of the teaching and educational experiences (O’Neill, 2009).

**Figure 1: Traditional Classroom Layout**
**Figure 2: Horseshoe or Semi-Circular Classroom Layout**

This paper elaborates on the utilization of AR to create new layouts in architecture classrooms allowing for multiple functions. In theory-based classes, the effectiveness of communication can impact the architectural classroom layout. While there are several architectural classroom layout arrangements, these three are the most popular: 1. The traditional arrangement (see figure 2.1), which consists of six or more rows of chairs organized equidistant in a line, or according to McCorskey and McVetta (1978) state “something like tombstones in a military cemetery”. Research has shown that 90 percent of architectural classrooms on a university campus persist in this arrangement; 2. The horseshoe or semi-circular arrangement (see Figure 2.2) is usually used for large classes, such as seminars.

**Figure 3: Modular Classroom Layout**

The third common type of seating arrangement is modular (see Figure.3). This arrangement is mainly employed in specialized classrooms such as science laboratories and in primary schools.

**3. Potentials of AR Application in Higher Education Centers**

It is expected to face a great increase in AR application in near future around 2014; this is due to the advancement of hardware and software (Chi et al., 2013). According to Gartner (2013) approximately 30% of workers will be using some applications and forms of AR capability by 2014. AR and other virtual digital displays can revolutionize the way occupants interact within architectural spaces (Lehman, 2010). AR has opened possibilities for direct experiments in the
greater context of immersive virtual learning allowing users to visualise the real environment (Kaufmann, 2010). This application will allow students to accommodate architectural related knowledge with its content.

3.1 The Advantage of AR in Educational Canters

Research has revealed that the educational value of an AR system is high and can provide additional motivation for students (Freitas et al. 2008). Usability testing of the AR system in schools has been carried out by researchers (Balog et al. 2007) and both qualitative and quantitative research indicates that this system entails cost-effective support for the users (Medicherla et al. 2010). Leona Lehman highlights five key points regarding how AR will help designers and occupants to have a better place: (Lehman, 2010).

**Explore:** AR technology enables the user to travel virtually; it also enables the user not only to see but touch and feel the sense of space.

**Relax:** AR technology creates a desirable place to de-stress.

**Learn:** AR technology provides a clearer presentation of concepts for new learners.

**Socialize:** AR technology provides many opportunities for interaction can provide outsource lecturer and attend virtual meetings.

**Play:** AR technology allows for a traditional space to transform into a game room, interactive “movie room”, recreational space or an office.

These key points can guide educators to create an adaptable functional space providing students with a social setting that allows for exploration and creativity within a stimulating environment.

3.2 Incentive of AR application in Architecture Classrooms

This paper will identify the action required, the benefits and challenges of each step, and will review the use of technology in the design process. Recent studies indicate that design students get precedent information through virtual archives to develop design projects (Senbel, 2013). This size of display areas is a major consideration which corresponds with the size of the audience. Researchers have shown that most design activities can be featured in three sizes: large monitors, wall-sized displays, and room-sized displays. The versatility of displaying ideas can encompass all variables of visuals from rough form to completely developed visuals in virtual format in the real world. Communicating the message to learners in a more effective manner through encompassing AR for all sizes of groups provides opportunity for all involved to view the process of needed change.
4. Reviewing Design Learning Activities in Architectural Classroom

Education centers of 21st century should provide a space that educators consider to various needs of learners to make them multi task to challenge and deal in a team, cooperate with each other, while collaborating effectively with ever-changing technology. Therefore the place should provide all these activities to run smoothly in classroom environment (Helm, et al., 2010). Developing an inclusive design approach is claimed to be significantly influential to successful design activities with view to the concept of automation in architecture design (Heylighen, 2012).

In the context of classrooms, several types of design are taught: product design; interactive design; architectural and interior design; and, graphic design. The stages and structure of design for all types is a process of creation ending in the final presentation (Khan, A. 2009) The five stages of design are: creation (concept design, site visit, case study); modification (how changes can be made and edited based on the requirements to standardise the design); communication (communication within the team of designers); collaboration (collaboration with other designers and professionals); and demonstration (display the final result to the client and/or public) (Khan, A. 2009). However these stages tend to blend into each other.

In considering all design stages, this paper discusses the reasons that design development needs to be improved in terms of technology application while knowing the main constrains such as time, visualization of idea and demonstration. AR can display building technology; application of the project not only displaying for students how the project is being built, but also preparing the project for implementation and construction. Figure 4 displays use of horizontal and vertical work surfaces.

Figure 4: Use of Digital and Analog Tools, Use of Horizontal and Vertical Work Surfaces (Khan A., 2009)

4.1 AR Impacts on Architectural Project Stages

Computer applications are mainly involved with creation and modification activities and are now used for purposes such as illustration, drafting and technical drawing. A recent experimental study indicates that application of 3D sculpt sketches (as one of the benefits of AR technology) is a suitable tool for conceptual design. And the results declare the effectiveness of 3D sculpt sketches for enhancement of 2D drawings production in early stages of design (Alcaide-Marzal, 2012). However, it is essential to highlight that the role of designers from creation to implementation remains the same (Khan, A., 2009). As research shows modification of design, during the stage of demonstration is an essential pedagogical implement that has an unsystematic theory in architecture design studios (Oh, 2012). Therefore having AR display techniques in architectural classrooms, allows users to experience a variety of case studies, techniques, and knowledge input to develop a project in a systematic way and enables students to interact with them by changing the scale, manipulating, rotating, analysing and combining images. These techniques greatly enhance the student’s visualization and understanding of all design stages in one space.
4.2 AR in Relation to Physical Spaces

In addition to the physical environment (sufficient ventilation and natural lighting), the adaptiveness of a classroom depends on the interior design elements. What is significant is the fact that designers need to plan the classroom for multiple functions and learning activities. Moreover, not only planning space to meet all learning expectation but also to promote creativity and productive behaviour, team work, and student to student interactions. For instance, teaching could be more efficient if the teacher could take the students to a site, which is difficult to do for every single session, therefore the lecturer can convey the experience with the aid of technology devices such as 3D models, gaming skills training, and AR books augmented in a real classroom. Researchers have shown that use of augmented reality in education provides strong contextual learning for students. Recent studies have shown that AR can be utilized from basic to complicated level of design and facilities in development of architecture and construction projects (Bae et al., 2013).

5. Research Overview

This study focuses on exploratory sequential implementation strategy in mixed methods. In practical terms, the dominant approach is skewed toward qualitative data through a semi-structured interview (Cresswell, 2008). The main objective is to conduct interviews of this type to study specific situations, and to validate information derived from literature review (Fraenkel et al., 2012). Purposeful sampling is selected as the primer sampling strategy in this study. In this procedure, the type of informants is formed based on the knowledge and the interest of informants to reflect the particular phenomenon. The initial sets of informants included 16 experts in architecture education, 12 experts as augmented reality educators from different universities. The intention of using mixed method strategy is that different results could be achieved through various strategies with the same respondent. Therefore qualitative research is recommended by Creswell, to be conducive to quantitative analysis in order to support the reliability and generalization of research (Creswell, 2012). Figure 5 shows the approach methods in this paper.

**Figure 5: Summary of Approached Methods**

6. Data Analysis

The qualitative interview is the primary technique used in this sequential mixed method. Three levels are proposed for classifying: 1. Verify the current features in education centers in private Malaysian universities to prove the successful integration of mono-functional classrooms into a multi-functional space through AR application; 2. Categorize gathered information to determine the advantages of AR in the classroom and select AR applications to be implemented; and 3. Analyse date with SPSS statistic T-test.

**Figure 6: Procedures of Data Analysing and Validation**
6.1 Data Analysis in Phase I

Architecture educators clarified the current features of mono-functional classrooms with a focus on furniture layout and the types of teaching activities utilized based on teaching content. Phase I interprets the perceptions of architecture educators from private Malaysian universities. The data was categorized and then coded in 5 parts. The categories of each group of questions are as follows:

Figure 7: Phase I- Part 1

Part 1- Significance of Classroom Redesign

Table 2: Data Coding- Phase I - Part 1

In the first part from the analysis of ‘Interview Part 1 - Phase I’ three questions were analyzed regarding the importance of classroom design layout. The results indicated three areas of issue as follows: 1. Classroom Size; 2. Functionality; and, 3. Layout. Respondents stated that the classroom design layout creates a static situation that limits interactive activities. Research indicates that students have less interaction with educators in an architectural classroom due to the aging infrastructure of the building. A majority of architectural classroom design is based on the traditional education method.

Part 2-Significance of Space Layout Design

Figure 1: Phase I - Part 2

In Part 2 the content of questions was designed to ascertain the importance of layout design issues in classrooms. Figure 8 displays this objective, therefore allowing the researcher to achieve an insight from respondents as to whether the classrooms design layouts are adaptive. As is shown in table 3, data coding of Part 2 is categorized based on the terms used by respondents.

Table 1: Data Coding- Phase I - Part 2

In the second part of the analysis of ‘Interview Part 2-Phase I’ four questions are analyzed regarding the; time spent in classroom; harmony of teaching methods in regards to classroom furniture layout; the use of the same classroom for various courses; and, effectiveness of classroom features in teaching performance are the main terms derived from the literature review. Classroom layout can influence students to reach the highest point of learning although this can be limited through the use of traditional classroom furniture and layout. As Steelcase
researchers 2011 mentioned a successful learning is through a type of classroom that conveys a sense of exploration, learning and enjoyment.

According to Steelcase researcher on higher education designers, and facilities professionals are focusing on multi-functional architectural classrooms: “offer (ing) different types of spaces for students to make them intentional about what they work on during project phases” (Steelcase, 2011). The most important achievement through the flexibility of the classrooms layout should be the procurement of interaction. In other words, flexibility should lift the classrooms out of mono-functionality to multi functionality. The majority of respondents highlighted enhancing the performance and features of classrooms.

Part 3- Need of Multi-functional Space in Architecture Classrooms

This section of research focus is to recognize the process of design activities in architectural classrooms from the point view of the experts in education. Table 4 shows the Data Coding - Part 3 of the design stages where most of the respondents agreed that the design stages develop from ideation to demonstration.

Table 2: Data Coding- Phase I - Part 3

Grouping the design stages into five stages of: creation (concept design, site visit, case study) modification; (how we can make changes and edit the design based on the requirements to standardise the design); communication (communication of the team of designers); collaboration (collaboration with other designer and professions); and demonstration (display the final result to the client and public). The majority of the respondents agreed on having these five stages as the main stages of an architecture design project. AR can greatly help to develop these stages inside the classroom. Although modification, communication and collaboration are types of activities that usually take place in an outdoor space, AR can conduct these activities in an indoor immersive environment (Khan, A., 2009).

Part 4 Technology Integration in Arch classroom

In this part of the paper, the level of technology use in classrooms is at the centre of attention. The respondents explained the need and level of technology currently used as one of the features of today’s classrooms. They also explained the relevance of current technology applications. Table 5 explains the responses that highlight the idea of technical integration in architectural classrooms.
There is a perceived need that today’s classroom need to be equipped with the most up-to-date technology whilst in reality architecture classrooms lack high technology and are only equipped with inadequate materials. While the cost of a modern technical system for architecture classrooms is high and requires support from the organizations, the benefits of multi-functional space and higher quality learning, outweighs the disadvantages.

**Part 5- Design Layout of Architecture Classroom of Private University of Malaysia**

And finally in conclusion, one of the questions was about the interviewee’s opinion in general regarding the general layout of classrooms in private universities. The researcher also sought agreement on whether private Malaysian universities have more limited space compared to public universities.

Table 6 shows that the majority of respondents stated that private universities need to maximize their use of space. Even in public universities where space is not so much of an issue, there is still the problem of functionalizing and personalizing the space.

**6.2 Data Analysis in Phase II**

During this stage of the research, phase II focuses on finding out the advantages of AR application in educational spaces. Therefore, AR expert are selected based on more than three years experience in AR education and practice. Correspondingly, Phase II is an answer toward Objective 2, the advantage of AR interaction in architectural studios and classrooms, and, Objective 3 of this study, suitable AR software and hardware to develop functionality enhancement in space. The facts that are discussed in this phase are Advantage of AR in classroom, and suitable AR features in architecture classroom, requirement for implementation of idea, and moreover the functionalities such as marker detection, TUI or NUI techniques and AR features were discussed to have a clear answer to development of respective theoretical contributions of this researching, phase II from AR expert point of view AR is able to bridge the gap between physical and digital environments by its very nature, and it can only exist to visualize full size furniture marker-based in large screen of the classrooms through the interaction of virtual and real environments.
**Part 1- Advantage of AR in Classroom**

The above graph shows the number of questions related to the advantage of AR in classrooms. Respondent’s answers highlight the reasons that education centers can benefit from classrooms as the most effective advancement of the virtual world. Also in this section, the researcher has considered the possible limitation and barriers of having AR in classrooms.

**Table 5: Data Coding- Phase I - Part 6**

Table 7 shows the use of 3D visualization as the most important advantage of AR in classrooms. Also half of the respondents noted that a virtual display device is required and that the furniture and structure should provide the space itself for technology applications such as CAVE. The effectiveness of 3D visualization is mentioned as fundamental as basic devices and sufficient lighting. Thus sufficient and basic tools are necessary to run an AR system.

**Part 2- Advantage of AR integration in Education**

In this section of the research the focus is to discover the advantage of AR integration in education, and the impact of AR in performance time, creating an immersive learning environment. This researcher attempted to the correlation between collected data in order to study AR integration in architectural classrooms. Table 8 clearly displays the coded data showing the advantage of AR integration in education.

**Table 6: Data Coding- Phase II - Part 1**

A series of questions were designed to elicit the advantages and impact of AR integration in education by examining, quality of teaching content, reduction of teacher talk time (TTT), and increase of student learning time (SLT). Respondents also pointed to the use of virtual elements in historical contexts and the benefits use of 3D visuals. Access to an interactive screen is one solution in running a multi-functional AR system.

**Part 3- Suitable AR Features in Architecture**

In this section of the research the focus is to discover the advantage of AR integration in education, and the impact of AR in performance time, creating an immersive learning environment. This researcher attempted to the correlation between collected data in order to study AR integration in architectural classrooms. Table 8 clearly displays the coded data showing the advantage of AR integration in education.
Part 3 is regarding suitable AR features in the Architecture field as is shown in figure 14. This section supports the need for having a variety of functions inside an architecture classroom. Moreover this is one of most important parts of the interview.

**Table 7: Data Coding- Phase II - Part 2**

In table 9, the paper reviews the suitable AR features in architecture. Respondents highlighted adaptability in a space as one of the key characteristic of AR. This application can be used in classrooms but for projection purposes, HMD or eyewear devices can be utilized. Also examined is a range of architecture software compatible with AR such as Autocad and Sketch Up to develop AR application in classrooms, as well as AR Toolkit which can be programmed to develop virtual objects in space, in addition to basic devices such as webcam, large screens, computers, etc. In discussing projection, interviewees suggested that desktop AR applications are the best solution. HMD, desktop and compatible software and devices such as projectors to display on screen are the necessary equipment to have an AR multi-functional system.

**Part 4- Requirement for Implementation of Idea**

**Figure 8: Phase II- Part 4**

In this part, the researcher asked the interviewees about the level of technology used in the classrooms and the requirements of idea implementation. The responses are beneficial to this study as the experts gave their opinion about the techniques and requirements to implement the Adaptive Augmented Reality Classroom System.

**Table 8: Data Coding- Phase II - Part 3**

Table 11 shows that the majority of respondents replied that projection, recognition and outline are the most suitable features to be used in an AR multi-functional system; projection can be interacted on any flat screen, this application is the most common type of AR. The research has focused the two types of AR detecting techniques; marker based and marker-less. The marker tags identify the viewpoint of the real camera so the virtual object, e.g. a chair, can be rendered correctly. This part also focuses on AR to display full size furniture in architecture classrooms therefore the necessary hardware devices should be identified to develop an AARC system.

**Table 9: Data Coding- Phase II - Part 4**

**7. Findings**

The explication of the qualitative research including Phase I and Phase II conducted in an exploratory mixed method results in elaborated objectives of this paper as follows.

(i) Identifying the features of mono-functional as well as multi-functional classrooms.
(ii) Recognizing the advantages and disadvantages of AR in architectural classrooms.
(iii) Identifying the most suitable techniques of AR application in mono-functional spaces to promote a new idea for AR developers and educators and designers

**Phase I**

- Findings inferred from the analysis of ‘Interview Part 1 - Phase I’ have highlighted the importance of classroom development in private universities where the interviewees stressed concerns such as functionality and fewer resources. A paucity of flexible classroom layouts, thus limiting interactive activities, is a consistent concern. The layout plan of a classroom needs to provide users with maximum adaptability, in other words, to be designed in modular form or horseshoe form to make the AR displays possible. As it was mentioned by Steelcase researchers, 2011 yet most college classrooms are set up for Emerson’s era as a result, colleges and universities are transforming their teaching methods, reconsidering how they use tools and technology, and rethinking the spaces where education happens (Steelcase, 2011).

  **Figure 9: Proposed Layout plan for Adaptive AR Classroom**

- Findings inferred from the analysis of ‘Interview Part 2 - Phase I’, stresses the significance of layout design in classrooms, as design and learning activities are at the center of attention. Traditional classroom furniture and layout can negatively influence students. Moreover, in this section respondents were asked whether they use the same classroom to teach different modules because of limitations in class furniture and layout

- Findings inferred from the analysis of ‘Interview Part 3 - Phase I’, focuses on the need of multi-functional space in architecture classrooms, respondents pointed to a variety of design activities in architectural projects. This is important as all educators and education designers need to have a better understanding of activities in the architectural classroom.

- Findings inferred from the analysis of ‘Interview Part 4 - Phase I’ highlights the technology integration in architecture classrooms, the respondent emphasized how technology affects the level of information and quality of teaching, moreover it was mentioned that the current architectural classroom of sample universities are not suitable for the educators and students’ needs lack of materials. Correspondingly, the level of learning will improve. All of the interviewees highlighted that the tech oriented classrooms can greatly support a variety of teaching methods. Figure 17 displays the proposed display area which is suitable for a set of classrooms based on Limkokwing University architecture classroom design.

In part 5, an overall statement is made by respondents that space enhancement and technology integration that can support them as educators in being more creative. In other words, it can provide a better use of space, by having suitable facilities.

  **Figure 10: Proposed Layout plan for technology integration in architecture classrooms**
Phase II

In Part 1, the content of questions focuses on advantages of Augmented Reality in classrooms. The answers given by respondents, highlights the reasons education centers can benefit from classrooms as the most interesting advancement of the virtual world. Also in this part, the researcher has considered the possible limitation and barriers of AR in classrooms. The most important advantage of Augmented Reality in classrooms supports students using 3D visualization and correspondingly, it is highlighted that this impacts learning in a positive manner. The majority of respondents believe that the learning experience improves through AR application and creates an immersive environment within a physical environment. According to Krogh (2001) ‘Applying AR in architectural rooms is something beyond a complete interaction with digital technology.’ (Lehman, 2011)

Part 2 highlights the advantages of AR integration in education, the quality of teaching content is highlighted and having less TTT in the classroom is emphasized by respondents. Respondents pointed to the use of virtual elements in historical contents and the benefits of 3D visuals.

Part 3 findings review suitable AR features in architecture, and point out the flexibility of AR in space as one of its characteristics. A variety of compatible software were mentioned and interviewees agreed that an Adaptive AR system can be set up to create the required items related to particular functions such as workshops, seminars, drawing, history class, design illustration, and design communication, etc.

Part 4 review the requirement for implementation of Adaptive AR Classroom System, the majority of the respondents replied that projection, recognition and outline are the most suitable features to be used for an AR multi-functional system. The majority of the respondents replied the marker base technique is a suitable detection; this requires large markers to be located at the site. Most interviewees named the same objects and the researcher reached a saturation point indicating that the system need to be developed based on a series of software and hardware such as cameras, PC, large screen, projectors and software such as Google Sketch up, AR Toolkit, Flash, C++. Respondents agreed on the possible limitations toward the creation of room size virtual furniture in a classroom. The other basic devise is a panorama projection to detect the marker from a 360 angle, which needs to be installed from the ceiling. The next step is the rendering of a large scale which must be of a good quality.

Table 10: Reliability Test- Phase I

Normality test

For the analysis and answer to the research question, the mean of each dimension was calculated based on related questions. The new variables were subjected to normality test using one sample
Kolmogorov – Smirnov. Results of this test showed that all dimensions mean score were distributed normally; therefore the next statistical analysis parametric methods such as t test and analysis of variance were applied. Result of this test and also considering the skewness (lay down between -2 to +2) statistic for all dimension revealed that all variables can be considered as normally distributed variables so for inferential statistics, parametric method will be applied. All the p value of this test is more than 0.05 therefore all variables were distributed normally.

**Table 13: Normality Test- phase I**

**One sample T-test**

A sample t-test was applied to test whether the mean of traditional classroom layout, Limitation in classroom layout, design stages, importance of multifunctional layout, importance of VR in space, , the possibility of enhancement of classroom functionality, differing from a hypothesized value 3 (the average of 1 to 5 scales). In table 16 the results the above mentioned means are shown:

**Table 14: One Sample Statistic- Phase I**

**Repeated Measure**

To evaluate the difference among architectural dimensions including (1) Traditional layout, (2) Limitation in class layout, (3) Design stages, (4) Importance of multifunctional layout, (5) Importance of VR in space (6) Enhancement of classroom functionality, a repeated-measure ANOVA was applied. Mauchly's test was done to test the sphericity.

To answer the research question of this study repeated measure ANOVA followed by pair wise comparisons for 6 indicators was done. The result of Mauchly's Test of Sphericity was significant (p value< 0.05) for 6 dimensions which means that the assumptions of sphericity had been violated. Therefore degrees of freedom were corrected using Greenhouse-Geisser method. Results of ANOVA revealed that architecture dimensions were significantly different, F (36.505, 276.934) = 36.505, P value <0.05 and Partial Eta Squared= 0.333.

**Table 15: Pair wise comparisons for Architecture dimensions**

Table 15 shows the mean value of (4) Importance of multifunctional layout as the highest mean, was significantly different from the mean of item (2) Limitation in class layout, (5) Importance of VR in space, (6) Enhancement of classroom functionality. But the difference between mean of item (4) Importance of multifunctional layout with (1) Traditional layout and (3) Design stages was not statistically significant.

**Table 16: Mauchly's Test - Phase I**
The use of appropriate techniques such as 3D modelling, animation, video, sound, as well as mouse and motion interaction for creation of the system, will create an interactive and user-friendly experience for the first time for architecture AR users. Interviews showed that future users will be able to visualize the architecture contents based on the teaching methods and content of the program without having to physically create a different space. Research was conducted based on interviews and surveys; the interview was conducted both with architecture educators (16 interviewees) and Augmented Reality educators and practitioners (9 interviewees). Research instruments such as surveys were built in architecture from 74 samples, and in AR field 26 samples, the surveys were collected from non expert practitioners and educators from four universities. The research findings show that the majority of architecture experts agree that private universities have limited and unsuitable architecture teaching space. The results also show the needs for multi-functional architectural classrooms. In Phase II, the majority of the Augmented Reality experts support the idea of a possible system to optimize the use of space by having full size virtual furniture in classrooms. This can be developed to help the space designers and AARCS developers consider that NUI and TUI – vision based – marker-based technique are the most suitable AR techniques to create a multi-functional space.

Phase II

Reliability test
The reliability test is to ensure that another researcher will get the same result with the same theoretical framework and data (Von Hartman, R. 2007). A good way to ensure reliability in a case study is to collect as much reliable data and documents as possible.

Table 17: Reliability Test- Phase II

Descriptive statistics, alpha coefficients, and item-total correlation were used to initially analyze the survey data. Advantage of technology in classrooms; possibility of AR features in a classroom; optimizing the use of space with AR; enhancing educational activities with AR; and, suitable hardware and software detection, were measured on five point Likert scale (Punch, 2003).

The mean of each dimension was calculated based on related questions to analysis and answer the research question. The new variables were subjected to normality test using one sample Kolmogorov–Smirnov. Results of this test show that all dimensions mean score were distributed normally. Therefore, the next statistical analysis parametric methods such as t test and analysis of variance were applied. Result of this test and also considering the skewness (lay down between -2 to +2) statistic for all dimension revealed that all variables can be considered as normally distributed variables so for inferential statistics, parametric method will be applied (Gueorguieva et al., 2004)

Table 18: Normality Test- phase II
One sample T-test

A sample t-test was applied to test whether the mean of Technology, AR features, the possibility of AR Optimizations in use of space, also the possibility of AR in design activities enhancement differing from a hypothesized value 3 (the average of 1 to 5 scales). In table 16 the results the above mentioned means are shown:

Table 19: One Sample T-test Statistics - Phase II

To evaluate the difference among augmented reality dimensions including: (1) Technology in classroom, (2) AR features, (3) AR to optimize the use of space, (4) Enhancement of design activities, a repeated-measure ANOVA was applied. Mauchly's test was done to test the sphericity.
To answer the research question of this study repeated measure ANOVA followed by pair wise comparisons for 6 indicators was done. The result of Mauchly's Test of Sphericity was not significant (p value> 0.05) for 4 dimensions.

Results of ANOVA revealed that augmented reality dimensions were significantly different, F (3, 75) = 2.846, P value <0.05 and Partial Eta Squared= 0.102.

Table 20: Pair wise comparisons for augmented reality dimensions

Table 20 shows the mean value of (3) AR to optimize the use of space as the highest mean. This also declares that the difference between mean of item (3) AR to optimize the use of space with (1) Technology in classroom, (2) AR features and (4) Enhancement of design activities was not statistically different.

Table 21: Mauchly's Test - Phase II

8. Discussion

Findings of the evaluation based on the literature reviews and interviews indicates that a system which provides motion tracking features, allows users to interact with virtual objects without using other devices such as wired gloves. This is a more natural process for users. They can interact with virtual objects using motions and commands and bare fingers. This research can be applied in all office, school and higher educational spaces that have variety of activities; providing more flexibility while enhancing the quality of the contents being practiced more effectively compared to unanimated 2D. As Architecture industry develops stages toward digital information, more intuitive visualizations are required for an efficient use of information (Chi et al., 2013). Therefore, AR can generate flexibility in various spaces, in different perspectives and will stimulate human interaction in space.
Correspondingly, this paper proposed the concept of having multi functional classrooms based on teaching and learning activities. The objectives of this research were, firstly, to study the features of current architecture classroom of private Malaysian universities, and secondly, to study the advantage of having such a system in architectural design classroom. Ultimately, the objective of this research to recognize a suitable development methodology model for conceptualizing augmented reality system for architectural classroom techniques and features using augmented reality techniques such as tangible augmented reality user interface (TUI) as well as natural augmented reality user interface (NUI) techniques. An NUI can provide more intuitive User experience while increasing the AR usability (Bae at al., 2013).

8.1 Applying AR Technology to optimize the use of space

One of the solutions used by educators is to use each classroom for one kind of function, such as architecture theory or architecture drawing or architecture design, however it requires a large space to run the functions separately. Therefore the alternative solution is to solve this problem in real time and real environment through the development of an Augmented Reality multi-functional space. According to the Deputy Minister of Higher Education of Malaysia, private universities have a limitation of space compared to public universities. Researchers have shown that the main reason students have less interaction with educators in architectural classrooms is the aging infrastructure of buildings in addition to the limited teaching methods being practiced by educators.

The obtained result from interviews and literature reviews, have shown that architecture and built environments, are playing a new role in people’s lives. Because of technology advancement, Augmented Reality can link users with the real world and cater them with information; this information enables people to experience new places from a far-way distance. According to the Deputy Minister of Higher Education of Malaysia, designers and educators need to consider the application of AR technology as a solution to resolving space limitation. Research, incorporated with positive results, supports the use of computerization and AR technologies; transforming single-use classrooms into multi-functional architectural classrooms.

8.2 Potential Usability of AR Space divider and furniture

The items code is assigned to the marker to be detected by the camera. Interaction techniques using TUI and NUI will be incorporated into the system to be adapted and create objects as realistic as possible so that researchers can feel as though they are handling the real object. Projection, recognition, and outline are suitable features of AR in architecture classrooms to create an optimal use of space. The augmented item can be displayed on multiple large screens on every wall, while the camera tracks and renders each item to add information, i.e. if the lecturer shows students how a laser machine functions, the information on the main components, name, price, installation, duration to produce, material difference can be superimposed on the screen.
9. Conclusion: Recommendation of Research Implementation

The findings of the current research have several implications for future researches in the field of Augmented Reality. The comprehensive literature review on AR technology which involves areas in vision-based registration to generate 3D computer graphics, image processing methods, 3D computer graphics techniques, and motion tracking, would provide initial fundamental knowledge for future researchers in this field. The Tangible User Interface (TUI) and Natural User Interface (NUI) are useful findings for future researchers. AR requires computer vision to simulate human visual perception to understand the real world (Meer et al., 2000). Based on the 2D fiduciary marker, the 3D virtual world can be constructed with computer vision algorithms. Users can sense the stimuli generated by the AR system and perceive it with visual perception. The purpose of AR is to generate realistic virtual objects (Azuma, 1997). This allows users to perceive virtual objects as real objects and interact with them. Since the virtual objects are integrated in the real world, natural interaction is important.

The traditional educational classroom layout can promote basic learning skills, but not necessarily equip learners with intellectual skills associated with creativity. Due to the fact that current educational spaces cannot be easily adapted for a range of learning activities and courses, the importance of designing classroom and educational centre has come to educators’ attention for preparing sufficient space for limited functional spaces. Space design of current classrooms is mostly mono-functional in higher educational centres, rather than being multi-functional to serve a range of educational purposes. Thus, this research was conducted to help educational centres to run a more responsive environment for both students and teachers.

10. Recommendations for Future Study: Final Remarks

Recommendation for future study related to this current research can be conducted as follows:

I. The current research is a conceptualization of AR classrooms to optimize the use of space of private universities of Malaysia in order to expand the limitation of space in classroom. This research has highlighted the mono functionality of architectural classroom neglecting the various functions of architectural classroom. AR interaction and finger interactions will be applied; the finger tracking for interaction with 3-Dimensional information will be implemented. The difference between this study and other studies is that there is no projects conducted information in architectural classroom using full size virtual objects. Therefore, in-depth information of this research project can be integrated into the future research, so that AR architects can interact with the virtual objects with in-depth information. This means that users will be able to change the environment and virtual environment based on their needs.

II. The researcher provides the finding to software and system developers and develop this idea more in to implementation line to develop, a methodology model will be defined as the Interactive – Simulative software or system development life cycle for Augmented Reality (I-SSDLC-AR) can be and the baseline for their development methodology. They can either adopt or adapt the model for their development process.
III. This paper aims to provide suggestions on application of AR to provide learning opportunities for occupants of the respective environment.

IV. Therefore, future research can look into this aspect. Many more advance application can be used besides the AR mentioned techniques as students can interact with the immersive environment more easily. This application can be conducted through finger gesture recognition that can be implemented in future research applied to interact with virtual objects in the AR system. Also it helps to create different commands to interact through the AR system.

V. Future research can also work on tangible and natural user interface, to have voice recognition as another natural way of interaction. Voice recognition can be used to express commands to the AR system. A real sound environment that is merged with virtual auditory environments (Härmä et al., 2012). Simple commands are useful in an AR system, as supplementary interactions.

VI. Future research can also take into consideration that controlling 3D objects in real time using eyes is another field to study. In addition, intelligent augmented reality is a next generation of AR to create smart 3D objects in real time and environment.

VII. A usability testing of the AR system is important. A full fledge usability testing will be conducted in future research to improve problems that can be detected from the AR system based on other constructs then that can be used in this current research. Therefore, the users can use the system with high satisfaction and ease.

11. References


• The multi-functionality of classroom development in private universities is proposed.
• The learning experience improves through AR application and creates an immersive environment.
• Findings recommend AR technology integration in architecture classrooms.
• Suitable AR features in architecture classrooms: projection, outline and recognition.
• Findings provide space designers to consider NUI and TUI – vision based – marker-based technique.
**Development of Adaptive Architecture Classrooms through the Application of Augmented Reality in Private Universities of Malaysia**

**Abstract:** This paper scrutinizes the circumstances of the application of Augmented Reality (AR) technology to enhance the adaptability of architecture classrooms in private Malaysian university classrooms. This study aims to indicate the constraints of mono-functional classrooms in comparison to the potentials of multi-functional classrooms derived from AR application through an exploratory mixed method strategy. This paper expects to contribute towards recognition of suitable AR techniques which can be applied in the development of Adaptive-AR-Classroom-Systems (AARCS) in architecture classrooms. The findings, derived from the analysis, show current classrooms have limited functional spaces, and concludes that AR application can be used in design classrooms to provide variety of visuals and virtual objects that are required in conducting architecture projects in higher educational centres.

**Keywords:** Design Activity, Space Enhancement, Design Education, Architectural Design Augmented Reality.

1. **Introduction**

Over time, occupants often want to change the functional space of a room to accommodate new requirements. Likewise, with view to the educational environments, the allocated tasks and requirements of educators and students vary based on teaching and learning needs. In this regard, current educational spaces are not flexible enough to provide a variety of activities. The current educational spaces do not embody sufficient potential to be easily adapted for a range of transformable learning activities and courses (O’Neill, 2009). Therefore, the importance of designing classrooms and educational centres has come to educators’ attention when preparing sufficient space for limited functional spaces. Recent studies indicate that building transformation looks to provide versatile characteristics to mono-functional spaces, such as offices, to improve the functionality of the existing building (Romey, 2009). Creating collaborative learning environment is one of the growing importance fields, that studies on enhancement of facilities and learning environment, sustain teaching resources (Berglund et al, 2006).

According to (Niroumand, 2012) studies, the allocated functions for modern architecture are divided into two terms to cope with human multiplicity; primarily the mono-functional space which is type of space that is only suitable for a particular function or activity. Secondly, multi-functional space, which is an adaptive space in terms of design and facility, it can also support multiple activities in the same place (Imrie, 1998). In this paper, the focus is on the issues of architectural design, namely the functionalities and space role in architecture classrooms in higher educational centres.

The primary objective of this research is to study features of current architectural classrooms with a view to functionality of space. Also this research aims to review the benefits of AR appliance in today’s educational activities used in architectural classrooms. Identification of
suitable techniques of AR for development of adaptive architecture classroom is accordingly the ultimate objective aim of this paper.

**Rationales to develop Malaysian higher education centres**

In 2004 the former Prime Minister Abdullah Badawi, in his opening speech of the Malaysian Education Summit, stated that development of education is the priority objective, to be aided by an IT revolution in Malaysian universities. Thus, Malaysian universities have been under strong pressure by the government to improve the quality of education (Olanrewaju, 2011). According to the recent Malaysian Educational Plan 10 MP (2011-2015), universities are expected to contribute significantly to the national future Vision 2020 of transforming Malaysia into a first world country. The government also reduced the amount of direct control over universities (Olanrewaju, 2011).

There is a need to promote an integration of ICT into universities and to develop a more ‘intelligent’ approach toward education (Gupta, 2008). This paper refers to significance of Malaysian universities development with a view to the Vision 2020. The application of the most recent advancement of technology, namely AR, is an IT approach toward enhancement of educational centres functionality.

2. Functionality in Today’s Architecture Classroom

As higher education comes to terms with a new generation of students and changing technologies, space design is a significantly fundamental issue (Steelcase, 2011). A university’s role of information and knowledge delivery should consider that IT has drastically changed the education environment (Ismail, 2008). The respective changes have had a considerable impact on the types of functions and structures within university classrooms (Gayle et al., 2011). This study denotes that current educational spaces are not flexible enough to allow a variety of activities (O’Neill, 2009). Thus, this paper aims to explore ways to apply the suitable applications in IT to combine the virtual environments with actual environments called Augmented Reality (AR). In this regard, Gayle et al. (2011) suggests that every university that desires to be competitive in the 21st century has to consider IT applications as the most necessary tools in knowledge delivery. AR interacts with educational spaces by creating full scale sets of virtual furniture and virtual space dividers enabling users to interact with a variety of virtual spaces to enhance the functionality of the spaces.

**The Design Layout of the Classrooms**

Limited space in higher education environments with a view to the various needs of a new generation of students in learning, has led designers and researchers to consider the redesign of classrooms. The following is a response to the need for interactive learning environments through technology application.
Table 1: The problem in today’s classroom

According to the review of recent scholarly studies, it is inferred that most universities in Malaysia need to implement access to IT in the classroom (Ismail et al. 2008). According to Vicziany and Puteh (2004), Malaysian universities are still behind in IT usage in educational centres. AR applications within educational spaces can improve space functionality in higher education. ‘Adaptability and re-configurability’ are directly linked to the quality of the teaching and educational experiences (O’Neill, 2009).

Figure 1: Traditional Classroom Layout
Figure 2: Horseshoe or Semi-Circular Classroom Layout

This paper elaborates on the utilization of AR to create new layouts in architecture classrooms allowing for multiple functions. In theory-based classes, the effectiveness of communication can impact the architectural classroom layout. While there are several architectural classroom layout arrangements, these three are the most popular: 1. The traditional arrangement (see figure 2.1), which consists of six or more rows of chairs organized equidistant in a line, or according to McCorskey and McVetta (1978) state “something like tombstones in a military cemetery”. Research has shown that 90 percent of architectural classrooms on a university campus persist in this arrangement; 2. The horseshoe or semi-circular arrangement (see Figure 2.2) is usually used for large classes, such as seminars.

Figure 3: Modular Classroom Layout

The third common type of seating arrangement is modular (see Figure.3). This arrangement is mainly employed in specialized classrooms such as science laboratories and in primary schools.

3. Potentials of AR Application in Higher Education Centers

It is expected to face a great increase in AR application in near future around 2014; this is due to the advancement of hardware and software (Chi et al., 2013). According to Gartner (2013) approximately 30% of workers will be using some applications and forms of AR capability by 2014. AR and other virtual digital displays can revolutionize the way occupants interact within architectural spaces (Lehman, 2010). AR has opened possibilities for direct experiments in the greater context of immersive virtual learning allowing users to visualise the real environment (Kaufmann, 2010). This application will allow students to accommodate architectural related knowledge with its content.

3.1 The Advantage of AR in Educational Canters

Research has revealed that the educational value of an AR system is high and can provide additional motivation for students (Freitas et al. 2008). Usability testing of the AR system in schools has been carried out by researchers (Balog et al. 2007) and both qualitative and
quantitative research indicates that this system entails cost-effective support for the users (Medicherla et al. 2010). Leona Lehman highlights five key points regarding how AR will help designers and occupants to have a better place: (Lehman, 2010).

**Explore:** AR technology enables the user to travel virtually; it also enables the user not only to see but touch and feel the sense of space.

**Relax:** AR technology creates a desirable place to de-stress.

**Learn:** AR technology provides a clearer presentation of concepts for new learners.

**Socialize:** AR technology provides many opportunities for interaction can provide outsource lecturer and attend virtual meetings.

**Play:** AR technology allows for a traditional space to transform into a game room, interactive “movie room”, recreational space or an office.

These key points can guide educators to create an adaptable functional space providing students with a social setting that allows for exploration and creativity within a stimulating environment.

### 3.2 Incentive of AR application in Architecture Classrooms

This paper will identify the action required, the benefits and challenges of each step, and will review the use of technology in the design process. Recent studies indicate that design students get precedent information through virtual archives to develop design projects (Senbel, 2013). This size of display areas is a major consideration which corresponds with the size of the audience. Researchers have shown that most design activities can be featured in three sizes: large monitors, wall-sized displays, and room-sized displays. The versatility of displaying ideas can encompass all variables of visuals from rough form to completely developed visuals in virtual format in the real world. Communicating the message to learners in a more effective manner through encompassing AR for all sizes of groups provides opportunity for all involved to view the process of needed change.

### 4. Reviewing Design Learning Activities in Architectural Classroom

Education centers of 21st century should provide a space that educators consider to various needs of learners to make them multi task to challenge and deal in a team, cooperate with each other, while collaborating effectively with ever-changing technology. Therefore the place should provide all these activities to run smoothly in classroom environment (Helm, et al., 2010). Developing an inclusive design approach is claimed to be significantly influential to successful design activities with view to the concept of automation in architecture design (Heylighen, 2012).

In the context of classrooms, several types of design are taught: product design; interactive design; architectural and interior design; and, graphic design. The stages and structure of design for all types is a process of creation ending in the final presentation (Khan, A. 2009)The five stages of design are: creation (concept design, site visit, case study); modification (how
changes can be made and edited based on the requirements to standardise the design; communication (communication within the team of designers); collaboration (collaboration with other designers and professionals); and demonstration (display the final result to the client and/or public) (Khan, A. 2009). However these stages tend to blend into each other.

In considering all design stages, this paper discusses the reasons that design development needs to be improved in terms of technology application while knowing the main constrains such as time, visualization of idea and demonstration. AR can display building technology; application of the project not only displaying for students how the project is being built, but also preparing the project for implementation and construction. Figure 4 displays use of horizontal and vertical work surfaces.

**Figure 4: Use of Digital and Analog Tools, Use of Horizontal and Vertical Work Surfaces (Khan A., 2009)**

4.1 AR Impacts on Architectural Project Stages

Computer applications are mainly involved with creation and modification activities and are now used for purposes such as illustration, drafting and technical drawing. A recent experimental study indicates that application of 3D sculpt sketches (as one of the benefits of AR technology) is a suitable tool for conceptual design. And the results declare the effectiveness of 3D sculpt sketches for enhancement of 2D drawings production in early stages of design (Alcaide-Marzal, 2012). However, it is essential to highlight that the role of designers from creation to implementation remains the same (Khan, A., 2009). As research shows modification of design, during the stage of demonstration is an essential pedagogical implement that has an unsystematic theory in architecture design studios (Oh, 2012). Therefore having AR display techniques in architectural classrooms, allows users to experience a variety of case studies, techniques, and knowledge input to develop a project in a systematic way and enables students to interact with them by changing the scale, manipulating, rotating, analysing and combining images. These techniques greatly enhance the student’s visualization and understanding of all design stages in one space.

4.2 AR in Relation to Physical Spaces

In addition to the physical environment (sufficient ventilation and natural lighting), the adaptiveness of a classroom depends on the interior design elements. What is significant is the fact that designers need to plan the classroom for multiple functions and leaning activities. Moreover, not only planning space to meet all learning expectation but also to promote creativity and productive behaviour, team work, and student to student interactions. For instance, teaching could be more efficient if the teacher could take the students to a site, which is difficult to do for every single session, therefore the lecturer can convey the experience with the aid of technology devices such as 3D models, gaming skills training, and AR books augmented in a real classroom. Researchers have shown that use of augmented reality in education provides strong contextual learning for students. Recent studies have shown that AR can be utilized from basic to
complicated level of design and facilities in development of architecture and construction projects (Bae et al., 2013).

5. Research Overview

This study focuses on exploratory sequential implementation strategy in mixed methods. In practical terms, the dominant approach is skewed toward qualitative data through a semi-structured interview (Cresswell, 2008). The main objective is to conduct interviews of this type to study specific situations, and to validate information derived from literature review (Fraenkel et al., 2012). Purposeful sampling is selected as the primer sampling strategy in this study. In this procedure, the type of informants is formed based on the knowledge and the interest of informants to reflect the particular phenomenon. The initial sets of informants included 16 experts in architecture education, 12 experts as augmented reality educators from different universities. The intention of using mixed method strategy is that different results could be achieved through various strategies with the same respondent. Therefore qualitative research is recommended by Creswell, to be conducive to quantitative analysis in order to support the reliability and generalization of research (Creswell, 2012). Figure 5 shows the approach methods in this paper.

![Figure 5: Summary of Research Outline](image)

6. Data Analysis

The qualitative interview is the primary technique used in this sequential mixed method. Three levels are proposed for classifying: 1. Verify the current features in education centers in private Malaysian universities to prove the successful integration of mono-functional classrooms into a multi-functional space through AR application; 2. Categorize gathered information to determine the advantages of AR in the classroom and select AR applications to be implemented; and 3. Analyse date with SPSS statistic T-test.

![Figure 6: Procedures of Data Analysing and Validation](image)

6.1 Data Analysis in Phase I

Architecture educators clarified the current features of mono-functional classrooms with a focus on furniture layout and the types of teaching activities utilized based on teaching content. 

Phase 1 interprets the perceptions of architecture educators from private Malaysian universities. The data was categorized and then coded in 5 parts. The categories of each group of questions are as follows:

![Figure 7: Phase I- Part 1](image)
Part 1 - Significance of Classroom Redesign

Table 2: Data Coding - Phase I - Part 1

In the first part from the analysis of ‘Interview Part 1 - Phase I’ three questions were analyzed regarding the importance of classroom design layout. The results indicated three areas of issue as follows: 1. Classroom Size; 2. Functionality; and, 3. Layout. Respondents stated that the classroom design layout creates a static situation that limits interactive activities. Research indicates that students have less interaction with educators in an architectural classroom due to the aging infrastructure of the building. A majority of architectural classroom design is based on the traditional education method.

Part 2 - Significance of Space Layout Design

Figure 1: Phase I - Part 2

In Part 2 the content of questions was designed to ascertain the importance of layout design issues in classrooms. Figure 8 displays this objective, therefore allowing the researcher to achieve an insight from respondents as to whether the classrooms design layouts are adaptive. As is shown in table 3, data coding of Part 2 is categorized based on the terms used by respondents.

Table 1: Data Coding - Phase I - Part 2

In the second part of the analysis of ‘Interview Part 2-Phase I’ four questions are analyzed regarding the; time spent in classroom; harmony of teaching methods in regards to classroom furniture layout; the use of the same classroom for various courses; and, effectiveness of classroom features in teaching performance are the main terms derived from the literature review. Classroom layout can influence students to reach the highest point of learning although this can be limited through the use of traditional classroom furniture and layout. As Steelcase researchers 2011 mentioned a successful learning is through a type of classroom that conveys a sense of exploration, learning and enjoyment.

According to Steelcase researcher on higher education designers, and facilities professionals are focusing on multi-functional architectural classrooms: “offer (ing) different types of spaces for students to make them intentional about what they work on during project phases” (Steelcase, 2011). The most important achievement through the flexibility of the classrooms layout should be the procurement of interaction. In other words, flexibility should lift the classrooms out of mono-functionality to multi functionality. The majority of respondents highlighted enhancing the performance and features of classrooms.

Part 3 - Need of Multi-functional Space in Architecture Classrooms

Figure 2: Phase I - Part 3
This section of research focus is to recognize the process of design activities in architectural classrooms from the point of view of the experts in education. Table 4 shows the Data Coding - Part 3 of the design stages where most of the respondents agreed that the design stages develop from ideation to demonstration.

**Table 2: Data Coding- Phase I - Part 3**

Grouping the design stages into five stages of: **creation** (concept design, site visit, case study) **modification**; (how we can make changes and edit the design based on the requirements to standardise the design); **communication** (communication of the team of designers); **collaboration** (collaboration with other designer and professions); and **demonstration** (display the final result to the client and public). The majority of the respondents agreed on having these five stages as the main stages of an architecture design project. AR can greatly help to develop these stages inside the classroom. Although modification, communication and collaboration are types of activities that usually take place in an outdoor space, AR can conduct these activities in an indoor immersive environment (Khan, A., 2009).

**Part 4 Technology Integration in Arch classroom**

In this part of the paper, the level of technology use in classrooms is at the centre of attention. The respondents explained the need and level of technology currently used as one of the features of today’s classrooms. They also explained the relevance of current technology applications. Table 5 explains the responses that highlight the idea of technical integration in architectural classrooms.

**Table 3: Data Coding- Phase I - Part 4**

There is a perceived need that today’s classroom need to be equipped with the most up-to-date technology whilst in reality architecture classrooms lack high technology and are only equipped with inadequate materials. While the cost of a modern technical system for architecture classrooms is high and requires support from the organizations, the benefits of multi-functional space and higher quality learning, outweighs the disadvantages.

**Part 5- Design Layout of Architecture Classroom of Private University of Malaysia**

Figure 4: Phase I- Part 5
And finally in conclusion, one of the questions was about the interviewee’s opinion in general regarding the general layout of classrooms in private universities. The researcher also sought agreement on whether private Malaysian universities have more limited space compared to public universities.

**Table 4: Data Coding- Phase I - Part 5**

Table 6 shows that the majority of respondents stated that private universities need to maximize their use of space. Even in public universities where space is not so much of an issue, there is still the problem of functionalizing and personalizing the space.

### 6.2 Data Analysis in Phase II

During this stage of the research, phase II focuses on finding out the advantages of AR application in educational spaces. Therefore, AR expert are selected based on more than three years experience in AR education and practice. Correspondingly, Phase II is an answer toward Objective 2, the advantage of AR interaction in architectural studios and classrooms, and, Objective 3 of this study, suitable AR software and hardware to develop functionality enhancement in space. The facts that are discussed in this phase are Advantage of AR in classroom, and suitable AR features in architecture classroom, requirement for implementation of idea, and moreover the functionalities such as marker detection, TUI or NUI techniques and AR features were discussed to have a clear answer to development of respective theoretical contributions of this researching, phase II from AR expert point of view AR is able to bridge the gap between physical and digital environments by its very nature, and it can only exist to visualize full size furniture marker-based in large screen of the classrooms through the interaction of virtual and real environments.

**Part 1- Advantage of AR in Classroom**

**Figure 5: Phase II- Part 1**

The above graph shows the number of questions related to the advantage of AR in classrooms. Respondent’s answers highlight the reasons that education centers can benefit from classrooms as the most effective advancement of the virtual world. Also in this section, the researcher has considered the possible limitation and barriers of having AR in classrooms.

**Table 5: Data Coding- Phase I - Part 6**
Table 7 shows the use of 3D visualization as the most important advantage of AR in classrooms. Also half of the respondents noted that a virtual display device is required and that the furniture and structure should provide the space itself for technology applications such as CAVE. The effectiveness of 3D visualization is mentioned as fundamental as basic devices and sufficient lighting. Thus sufficient and basic tools are necessary to run an AR system.

**Part 2- Advantage of AR integration in Education**

![Figure 6: Phase II- Part 2](image)

In this section of the research the focus is to discover the advantage of AR integration in education, and the impact of AR in performance time, creating an immersive learning environment. This researcher attempted to the correlation between collected data in order to study AR integration in architectural classrooms. Table 8 clearly displays the coded data showing the advantage of AR integration in education.

**Table 6: Data Coding- Phase II - Part 1**

A series of questions were designed to elicit the advantages and impact of AR integration in education by examining, quality of teaching content, reduction of teacher talk time (TTT), and increase of student learning time (SLT). Respondents also pointed to the use of virtual elements in historical contexts and the benefits use of 3D visuals. Access to an interactive screen is one solution in running a multi-functional AR system.

**Part 3- Suitable AR Features in Architecture**

![Figure 7: Phase II- Part 3](image)

Part 3 is regarding suitable AR features in the Architecture field as is shown in figure 14. This section supports the need for having a variety of functions inside an architecture classroom. Moreover this is one of most important parts of the interview.

**Table 7: Data Coding- Phase II - Part 2**

In table 9, the paper reviews the suitable AR features in architecture. Respondents highlighted adaptability in a space as one of the key characteristic of AR. This application can be used in classrooms but for projection purposes, HMD or eyewear devices can be utilized. Also examined is a range of architecture software compatible with AR such as Autocad and Sketch Up to develop AR application in classrooms, as well as AR Toolkit which can be programmed to develop virtual objects in space, in addition to basic devices such as webcam, large screens, computers, etc. In discussing projection, interviewees suggested that desktop AR
applications are the best solution. HMD, desktop and compatible software and devices such as projectors to display on screen are the necessary equipment to have an AR multi-functional system.

**Part 4- Requirement for Implementation of Idea**

*Figure 8: Phase II- Part 4*

In this part, the researcher asked the interviewees about the level of technology used in the classrooms and the requirements of idea implementation. The responses are beneficial to this study as the experts gave their opinion about the techniques and requirements to implement the Adaptive Augmented Reality Classroom System.

**Table 8: Data Coding- Phase II - Part 3**

Table 11 shows that the majority of respondents replied that projection, recognition and outline are the most suitable features to be used in an AR multi-functional system; projection can be interacted on any flat screen, this application is the most common type of AR. The research has focused the two types of AR detecting techniques; marker based and marker-less. The marker tags identify the viewpoint of the real camera so the virtual object, e.g. a chair, can be rendered correctly. This part also focuses on AR to display full size furniture in architecture classrooms therefore the necessary hardware devices should be identified to develop an AARC system.

**Table 9: Data Coding- Phase II - Part 4**

7. Findings

The explication of the qualitative research including Phase I and Phase II conducted in an exploratory mixed method results in elaborated objectives of this paper as follows.

(i) Identifying the features of mono-functional as well as multi-functional classrooms.
(ii) Recognizing the advantages and disadvantages of AR in architectural classrooms.
(iii) Identifying the most suitable techniques of AR application in mono-functional spaces to promote a new idea for AR developers and educators and designers

**Phase I**

- Findings inferred from the analysis of ‘Interview Part 1- Phase I’ have highlighted the importance of classroom development in private universities where the interviewees stressed concerns such as functionality and fewer resources. A paucity of flexible classroom layouts, thus limiting interactive activities, is a consistent concern. The layout plan of a classroom needs to provide users with maximum adaptability, in other words, to be designed in modular form or horseshoe form to make the AR displays possible. As it was mentioned by Steelcase researchers, 2011 yet most college classrooms are set up for Emerson’s era as a result, colleges and
universities are transforming their teaching methods, reconsidering how they use tools and technology, and rethinking the spaces where education happens (Steelcase, 2011).

**Figure 9: Proposed Layout plan for Adaptive AR Classroom**

- Findings inferred from the analysis of ‘Interview Part 2 - Phase I’, stresses the significance of layout design in classrooms, as design and learning activities are at the center of attention. Traditional classroom furniture and layout can negatively influence students. Moreover, in this section respondents were asked whether they use the same classroom to teach different modules because of limitations in class furniture and layout.

- Findings inferred from the analysis of ‘Interview Part 3 - Phase I’, focuses on the need of multi-functional space in architecture classrooms, respondents pointed to a variety of design activities in architectural projects. This is important as all educators and education designers need to have a better understanding of activities in the architectural classroom.

- Findings inferred from the analysis of ‘Interview Part 4 - Phase I’ highlights the technology integration in architecture classrooms, the respondent emphasized how technology affects the level of information and quality of teaching, moreover it was mentioned that the current architectural classroom of sample universities are not suitable for the educators and students’ needs lack of materials. Correspondingly, the level of learning will improve. All of the interviewees highlighted that the tech oriented classrooms can greatly support a variety of teaching methods. Figure 17 displays the proposed display area which is suitable for a set of classrooms based on Limkokwing University architecture classroom design.

In part 5, an overall statement is made by respondents that space enhancement and technology integration that can support them as educators in being more creative. In other words, it can provide a better use of space, by having suitable facilities.

**Figure 10: Proposed Layout plan for technology integration in architecture classrooms**

**Figure 11: modular arrangement to have more interactive activities in Adaptive learning environment**

**Phase II**

In Part 1, the content of questions focuses on advantages of Augmented Reality in classrooms. The answers given by respondents, highlights the reasons education centers can benefit from classrooms as the most interesting advancement of the virtual world. Also in this part, the researcher has considered the possible limitation and barriers of AR in classrooms. The most important advantage of Augmented Reality in classrooms supports students using 3D visualization and correspondingly, it is highlighted that this impacts learning in a positive manner. The majority of respondents believe that the learning experience improves through AR
application and creates an immersive environment within a physical environment. According to Krogh (2001) ‘Applying AR in architectural rooms is something beyond a complete interaction with digital technology.’ (Lehman, 2011)

Part 2 highlights the advantages of AR integration in education, the quality of teaching content is highlighted and having less TTT in the classroom is emphasized by respondents. Respondents pointed to the use of virtual elements in historical contents and the benefits of 3D visuals.

Part 3 findings review suitable AR features in architecture, and point out the flexibility of AR in space as one of its characteristics. A variety of compatible software were mentioned and interviewees agreed that an Adaptive AR system can be set up to create the required items related to particular functions such as workshops, seminars, drawing, history class, design illustration, and design communication, etc.

Part 4 review the requirement for implementation of Adaptive AR Classroom System, the majority of the respondents replied that projection, recognition and outline are the most suitable features to be used for an AR multi-functional system. The majority of the respondents replied the marker base technique is a suitable detection; this requires large markers to be located at the site. Most interviewees named the same objects and the researcher reached a saturation point indicating that the system need to be developed based on a series of software and hardware such as cameras, PC, large screen, projectors and software such as Google Sketch up, AR Toolkit, Flash, C++. Respondents agreed on the possible limitations toward the creation of room size virtual furniture in a classroom. The other basic devise is a panorama projection to detect the marker from a 360 angle, which needs to be installed from the ceiling. The next step is the rendering of a large scale which must be of a good quality.

Table 10: Reliability Test- Phase I

Normality test

For the analysis and answer to the research question, the mean of each dimension was calculated based on related questions. The new variables were subjected to normality test using one sample Kolmogorov – Smirnov. Results of this test showed that all dimensions mean score were distributed normally; therefore the next statistical analysis parametric methods such as t test and analysis of variance were applied. Result of this test and also considering the skewness (lay down between -2 to +2) statistic for all dimension revealed that all variables can be considered as normally distributed variables so for inferential statistics, parametric method will be applied. All the p value of this test is more than 0.05 therefore all variables were distributed normally.

Table 13: Normality Test- phase I

One sample T-test
A sample t-test was applied to test whether the mean of traditional classroom layout, Limitation in classroom layout, design stages, importance of multifunctional layout, importance of VR in space, the possibility of enhancement of classroom functionality, differing from a hypothesized value 3 (the average of 1 to 5 scales). In table 16 the results the above mentioned means are shown:

Table 14: One Sample Statistic- Phase I

Repeated Measure
To evaluate the difference among architectural dimensions including (1) Traditional layout, (2) Limitation in class layout, (3) Design stages, (4) Importance of multifunctional layout, (5) Importance of VR in space (6) Enhancement of classroom functionality, a repeated-measure ANOVA was applied. Mauchly's test was done to test the sphericity.

To answer the research question of this study repeated measure ANOVA followed by pair wise comparisons for 6 indicators was done. The result of Mauchly's Test of Sphericity was significant (p value< 0.05) for 6 dimensions which means that the assumptions of sphericity had been violated. Therefore degrees of freedom were corrected using Greenhouse-Geisser method. Results of ANOVA revealed that architecture dimensions were significantly different, F (36.505, 276.934) = 36.505, P value <0.05 and Partial Eta Squared= 0.333.

Table 15: Pair wise comparisons for Architecture dimensions

Table 15 shows the mean value of (4) Importance of multifunctional layout as the highest mean, was significantly different from the mean of item (2) Limitation in class layout, (5) Importance of VR in space, (6) Enhancement of classroom functionality. But the difference between mean of item (4) Importance of multifunctional layout with (1) Traditional layout and (3) Design stages was not statistically significant.

Table 16: Mauchly's Test - Phase I

The use of appropriate techniques such as 3D modelling, animation, video, sound, as well as mouse and motion interaction for creation of the system, will create an interactive and user-friendly experience for the first time for architecture AR users. Interviews showed that future users will be able to visualize the architecture contents based on the teaching methods and content of the program without having to physically create a different space. Research was conducted based on interviews and surveys; the interview was conducted both with architecture educators (16 interviewees) and Augmented Reality educators and practitioners (9 interviewees). Research instruments such as surveys were built in architecture from 74 samples, and in AR field 26 samples, the surveys were collected from non expert practitioners and educators from four universities. The research findings show that the majority of architecture experts agree that private universities have limited and unsuitable architecture teaching space. The results also show the needs for multi-functional architectural classrooms. In Phase II, the majority of the
Augmented Reality experts support the idea of a possible system to optimize the use of space by having full size virtual furniture in classrooms. This can be developed to help the space designers and AARCS developers consider that NUI and TUI – vision based – marker-based technique are the most suitable AR techniques to create a multi-functional space.

**Phase II**

**Reliability test**

The reliability test is to ensure that another researcher will get the same result with the same theoretical framework and data (Von Hartman, R. 2007). A good way to ensure reliability in a case study is to collect as much reliable data and documents as possible.

**Table 17: Reliability Test- Phase II**

Descriptive statistics, alpha coefficients, and item-total correlation were used to initially analyze the survey data. Advantage of technology in classrooms; possibility of AR features in a classroom; optimizing the use of space with AR; enhancing educational activities with AR; and, suitable hardware and software detection, were measured on five point Likert scale (Punch, 2003).

The mean of each dimension was calculated based on related questions to analysis and answer the research question. The new variables were subjected to normality test using one sample Kolmogorov–Smirnov. Results of this test show that all dimensions mean score were distributed normally. Therefore, the next statistical analysis parametric methods such as t test and analysis of variance were applied. Result of this test and also considering the skewness (lay down between -2 to +2) statistic for all dimension revealed that all variables can be considered as normally distributed variables so for inferential statistics, parametric method will be applied (Gueorguieva et al., 2004)

**Table 18: Normality Test- phase II**

**One sample T-test**

A sample t-test was applied to test whether the mean of Technology, AR features, the possibility of AR Optimizations in use of space, also the possibility of AR in design activities enhancement differing from a hypothesized value 3 (the average of 1 to 5 scales). In table 16 the results the above mentioned means are shown:

**Table 19: One Sample T-test Statistics - Phase II**

To evaluate the difference among augmented reality dimensions including: (1) Technology in classroom, (2) AR features, (3) AR to optimize the use of space, (4) Enhancement of design
activities, a repeated-measure ANOVA was applied. Mauchly's test was done to test the sphericity.
To answer the research question of this study repeated measure ANOVA followed by pair wise comparisons for 6 indicators was done. The result of Mauchly's Test of Sphericity was not significant (p value> 0.05) for 4 dimensions.

Results of ANOVA revealed that augmented reality dimensions were significantly different, \( F(3, 75) = 2.846, P \text{ value} < 0.05 \) and Partial Eta Squared= 0.102.

Table 20: Pair wise comparisons for augmented reality dimensions

Table 20 shows the mean value of (3) AR to optimize the use of space as the highest mean. This also declares that the difference between mean of item (3) AR to optimize the use of space with (1) Technology in classroom, (2) AR features and (4) Enhancement of design activities was not statistically different.

Table 21: Mauchly's Test - Phase II

8. Discussion

Findings of the evaluation based on the literature reviews and interviews indicates that a system which provides motion tracking features, allows users to interact with virtual objects without using other devices such as wired gloves. This is a more natural process for users. They can interact with virtual objects using motions and commands and bare fingers. This research can be applied in all office, school and higher educational spaces that have variety of activities; providing more flexibility while enhancing the quality of the contents being practiced more effectively compared to unanimated 2D. As Architecture industry develops stages toward digital information, more intuitive visualizations are required for an efficient use of information (Chi et al., 2013). Therefore, AR can generate flexibility in various spaces, in different perspectives and will stimulate human interaction in space.

Correspondingly, this paper proposed the concept of having multi functional classrooms based on teaching and learning activities. The objectives of this research were, firstly, to study the features of current architecture classroom of private Malaysian universities, and secondly, to study the advantage of having such a system in architectural design classroom. Ultimately, the objective of this research to recognize a suitable development methodology model for conceptualizing augmented reality system for architectural classroom techniques and features using augmented reality techniques such as tangible augmented reality user interface (TUI) as well as natural augmented reality user interface (NUI) techniques. An NUI can provide more intuitive User experience while increasing the AR usability (Bae at al., 2013).
8.1 Applying AR Technology to optimize the use of space

One of the solutions used by educators is to use each classroom for one kind of function, such as architecture theory or architecture drawing or architecture design, however it requires a large space to run the functions separately. Therefore the alternative solution is to solve this problem in real time and real environment through the development of an Augmented Reality multi-functional space. According to the Deputy Minister of Higher Education of Malaysia, private universities have a limitation of space compared to public universities. Researchers have shown that the main reason students have less interaction with educators in architectural classrooms is the aging infrastructure of buildings in addition to the limited teaching methods being practiced by educators.

The obtained result from interviews and literature reviews, have shown that architecture and built environments, are playing a new role in people’s lives. Because of technology advancement, Augmented Reality can link users with the real world and cater them with information; this information enables people to experience new places from a far-way distance. According to the Deputy Minister of Higher Education of Malaysia, designers and educators need to consider the application of AR technology as a solution to resolving space limitation. Research, incorporated with positive results, supports the use of computerization and AR technologies; transforming single-use classrooms into multi-functional architectural classrooms.

8.2 Potential Usability of AR Space divider and furniture

The items code is assigned to the marker to be detected by the camera. Interaction techniques using TUI and NUI will be incorporated into the system to be adapted and create objects as realistic as possible so that researchers can feel as though they are handling the real object. Projection, recognition, and outline are suitable features of AR in architecture classrooms to create an optimal use of space. The augmented item can be displayed on multiple large screens on every wall, while the camera tracks and renders each item to add information, i.e. if the lecturer shows students how a laser machine functions, the information on the main components, name, price, installation, duration to produce, material difference can be superimposed on the screen.

9. Conclusion: Recommendation of Research Implementation

The findings of the current research have several implications for future researches in the field of Augmented Reality. The comprehensive literature review on AR technology which involves areas in vision-based registration to generate 3D computer graphics, image processing methods, 3D computer graphics techniques, and motion tracking, would provide initial fundamental knowledge for future researchers in this field. The Tangible User Interface (TUI) and Natural User Interface (NUI) are useful findings for future researchers. AR requires computer vision to simulate human visual perception to understand the real world (Meer et al., 2000). Based on the
2D fiduciary marker, the 3D virtual world can be constructed with computer vision algorithms. Users can sense the stimuli generated by the AR system and perceive it with visual perception. The purpose of AR is to generate realistic virtual objects (Azuma, 1997). This allows users to perceive virtual objects as real objects and interact with them. Since the virtual objects are integrated in the real world, natural interaction is important.

The traditional educational classroom layout can promote basic learning skills, but not necessarily equip learners with intellectual skills associated with creativity. Due to the fact that current educational spaces cannot be easily adapted for a range of learning activities and courses, the importance of designing classroom and educational centre has come to educators’ attention for preparing sufficient space for limited functional spaces. Space design of current classrooms is mostly mono-functional in higher educational centres, rather than being multi-functional to serve a range of educational purposes. Thus, this research was conducted to help educational centres to run a more responsive environment for both students and teachers.

10. Recommendations for Future Study: Final Remarks

Recommendation for future study related to this current research can be conducted as follows:

I. The current research is a conceptualization of AR classrooms to optimize the use of space of private universities of Malaysia in order to expand the limitation of space in classroom. This research has highlighted the mono functionality of architectural classroom neglecting the various functions of architectural classroom. AR interaction and finger interactions will be applied; the finger tracking for interaction with 3-Dimensional information will be implemented. The difference between this study and other studies is that there is no projects conducted information in architectural classroom using full size virtual objects. Therefore, in-depth information of this research project can be integrated into the future research, so that AR architects can interact with the virtual objects with in-depth information. This means that users will be able to change the environment and virtual environment based on their needs.

II. The researcher provides the finding to software and system developers and develop this idea more in to implementation line to develop, a methodology model will be defined as the Interactive – Simulative software or system development life cycle for Augmented Reality (I-SSDLC-AR) can be and the baseline for their development methodology. They can either adopt or adapt the model for their development process.

III. This paper aims to provide suggestions on application of AR to provide learning opportunities for occupants of the respective environment.

IV. Therefore, future research can look into this aspect. Many more advance application can be used besides the AR mentioned techniques as students can interact with the immersive environment more easily. This application can be conducted through finger gesture recognition that can be implemented in future research applied to interact with
virtual objects in the AR system. Also it helps to create different commands to interact through the AR system.

V. Future research can also work on tangible and natural user interface, to have voice recognition as another natural way of interaction. Voice recognition can be used to express commands to the AR system. A real sound environment that is merged with virtual auditory environments (Härmä et al., 2012). Simple commands are useful in an AR system, as supplementary interactions.

VI. Future research can also take into consideration that controlling 3D objects in real time using eyes is another field to study. In addition, intelligent augmented reality is a next generation of AR to create smart 3D objects in real time and environment.

VII. A usability testing of the AR system is important. A full fledge usability testing will be conducted in future research to improve problems that can be detected from the AR system based on other constructs then that can be used in this current research. Therefore, the users can use the system with high satisfaction and ease.

11. References


Figure 1: Traditional Classroom Layout
Figure 2: Horseshoe or Semi-Circular Classroom Layout
Figure 3: Modular Classroom Layout
Figure 4: Use of Digital and Analog Tools, Use of Horizontal and Vertical Work Surfaces (Khan A., 2009)
Figure 5: Summary of Research Outline
Figure 6: Procedures of Data Analysing and Validation
Figure 7: Phase I- Part 1
Figure 8: Phase I- part 2
Variety of activities in architecture classroom

Q8

Need of multi-Functional Space in Architecture Classrooms

Figure 9: Phase I- Part 3
Figure 10: Phase I- Part 4
Figure 11: Phase I- Part 5
Figure 12: Phase II - Part 1
Figure 13: Phase II- Part 2
Figure 14: Phase II- Part 3
Figure 15: Phase II- Part 4
PROPOSED DEDICATED STUDIO

SUMMARY
VENUE: CLASS 43
NUMBER OF STUDENTS: 20

RESOURCES REQUIRED:
1. WORKSTATION (20)
   - 20 nos. of 4’Wx2.5’Tx2.5’H TABLE
   - 4’H PARTITION
   - 20 nos. of 16”WX 2’DX2’3”H DRAWER
   - 40 PLUG POINTS (2 EACH)

2. DISCUSSION TABLE (7)
   - 7 nos. of 2.5’X5’ TABLE

3. BUILT-IN STORAGE (1)
   - (11.5”X2.5”X18”H)

4. SOFTBOARD (1)
   - (11.5”X2.25”X10”H)

4. CLEANING & PAINTING WORK

LAYOUT PLAN

Figure 16: Proposed Layout Plan for Adaptive AR Classroom
Figure 17: Proposed Layout Plan for Technology Integration in Architecture Classrooms

The proposed display area, Marker Based designed screen to show variety of functions

More interactive furniture layout to be designed in classrooms that supports variety of learning activities
PROPOSED DEDICATED STUDIO

Figure 18: Modular Arrangement to Have More Interactive Activities in Adaptive Learning Environment
<table>
<thead>
<tr>
<th>Place</th>
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<tr>
<td></td>
<td>• limited flexibility inside the classroom</td>
</tr>
<tr>
<td></td>
<td>• Technology is poorly integrated into classroom (Steelcase researchers, 2011).</td>
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<td></td>
<td>• The classroom design is based on traditional layout (rows of chairs with desks attached).</td>
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<tr>
<td></td>
<td>• Use of the same classroom for different courses and lessons</td>
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Table 1: The problem in today’s classroom
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<td>Teaching Methods</td>
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<td>6</td>
<td>AR Application</td>
<td>5</td>
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<tr>
<td>More SLT</td>
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<td>3D Visualization</td>
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<td>Enhance Quality of Learning</td>
<td>8</td>
<td>to be Generalized</td>
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<tr>
<td></td>
<td></td>
<td>Interactive Screen</td>
<td></td>
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<td></td>
<td>Virtual Environment</td>
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<td>Table 9: Data Coding- Phase II - Part 2</td>
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<td>Terms Q11</td>
<td>No of responses</td>
<td>Terms Q12</td>
<td>No of responses</td>
<td>Terms Q13</td>
<td>No of responses</td>
</tr>
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<td>-----------</td>
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<td>AR Application</td>
<td>7</td>
<td>Software Development</td>
<td>7</td>
<td>Room Size Virtual Furniture</td>
<td>4</td>
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<td>Flexibility in Environment</td>
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<td>Hardware Development</td>
<td>6</td>
<td>Indoor AR Application</td>
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<td>Real Size Virtual Furniture</td>
<td>8</td>
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<td>Basic Devices</td>
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<td>Desktop AR</td>
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<td>Necessary Equipment</td>
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Table 10: Data Coding - Phase II - Part 3
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<th>Terms Q16</th>
<th>No of responses</th>
<th>Terms Q17</th>
<th>No of responses</th>
<th>Terms Q18</th>
<th>No of responses</th>
<th>Terms Q19</th>
<th>No of responses</th>
</tr>
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<tbody>
<tr>
<td>Projection</td>
<td>6</td>
<td>Marker Based</td>
<td>6</td>
<td>C++, Flash</td>
<td>6</td>
<td>Real Size of physical objects</td>
<td>5</td>
<td>User interaction</td>
<td>3</td>
</tr>
<tr>
<td>Outline</td>
<td>5</td>
<td>Marker Less</td>
<td>2</td>
<td>Autodesk, ARtoolkit</td>
<td>2</td>
<td>Tracking</td>
<td>4</td>
<td>Tangible User Interface (TUI)</td>
<td>2</td>
</tr>
<tr>
<td>Recognition</td>
<td>1</td>
<td></td>
<td></td>
<td>Camera, Projector</td>
<td>7</td>
<td>Rendering of virtual image</td>
<td>2</td>
<td>Quality of learning</td>
<td>2</td>
</tr>
<tr>
<td>Location</td>
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<td></td>
<td></td>
<td>Large Screen</td>
<td>8</td>
<td>3D Visualization on large screen</td>
<td>5</td>
<td>3D Visualization</td>
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<td>Hologram</td>
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<td></td>
<td>PC</td>
<td>7</td>
<td></td>
<td></td>
<td>Natural User Interface (NUI)</td>
<td>5</td>
</tr>
<tr>
<td>Marker</td>
<td>8</td>
<td></td>
<td></td>
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Table 11: Data Coding- Phase II - Part 4
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<th>Variance</th>
<th>Std. Deviation</th>
<th>N of Items</th>
<th>Cronbach's Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traditional Layout Mean</strong></td>
<td>28.29</td>
<td>5.08</td>
<td>2.25</td>
<td>7</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>Design Stage Mean</strong></td>
<td>20.52</td>
<td>3.76</td>
<td>1.93</td>
<td>5</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>Importance of Multi Functional Space</strong></td>
<td>23.85</td>
<td>4.45</td>
<td>2.11</td>
<td>6</td>
<td>0.71</td>
</tr>
<tr>
<td><strong>Importance of VR Enhancement of Classroom</strong></td>
<td>29.74</td>
<td>7.6</td>
<td>2.77</td>
<td>7</td>
<td>.70</td>
</tr>
<tr>
<td><strong>Enhancement of Classroom Functionality</strong></td>
<td>28.77</td>
<td>5.79</td>
<td>2.40</td>
<td>7</td>
<td>.73</td>
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Table 12: Reliability Test- Phase I
<table>
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<th>Dimension</th>
<th>Mean</th>
<th>SD</th>
<th>Skewness</th>
<th>Kolmogorov-Smirnov Z</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Layout mean</td>
<td>4.03</td>
<td>0.30</td>
<td>-1.46</td>
<td>2.12</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Limitation in class layout mean</td>
<td>3.56</td>
<td>0.49</td>
<td>-0.10</td>
<td>2.32</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Design stages mean</td>
<td>4.06</td>
<td>0.33</td>
<td>0.16</td>
<td>1.47</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>multifunctional layout mean</td>
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<td>0.35</td>
<td>-0.54</td>
<td>1.40</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>VR in space</td>
<td>4.24</td>
<td>0.39</td>
<td>-0.17</td>
<td>0.92</td>
<td>0.360</td>
</tr>
<tr>
<td>Enhancement of classroom functionality</td>
<td>4.12</td>
<td>0.28</td>
<td>0.34</td>
<td>1.49</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Table 13: Normality Test- phase I
### Variables

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>t</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Layout mean</td>
<td>4.03</td>
<td>.30</td>
<td>29.36</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Limitation in class layout mean</td>
<td>3.56</td>
<td>.49</td>
<td>9.92</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Design stages mean</td>
<td>4.06</td>
<td>.33</td>
<td>27.25</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Importance of multifunctional layout mean</td>
<td>3.97</td>
<td>1.67</td>
<td>23.84</td>
<td>&lt;0.05</td>
</tr>
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<td>4.24</td>
<td>2.77</td>
<td>27.15</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Enhancement of classroom functionality mean</td>
<td>4.11</td>
<td>.28</td>
<td>34.06</td>
<td>&lt;0.05</td>
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</table>

Table 14: One Sample Statistic- Phase I
<table>
<thead>
<tr>
<th>Measure:MEASURE_1</th>
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<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>(I) Architecture</td>
<td>(J) Architecture</td>
<td>Mean Difference (I-J)</td>
<td>Sig.</td>
<td></td>
</tr>
<tr>
<td>(1) Traditional layout</td>
<td>(2) Limitation in class layout</td>
<td>0.47**</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>(1) Traditional layout</td>
<td>(3) Design stages</td>
<td>-0.026</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>(1) Traditional layout</td>
<td>(4) Importance of</td>
<td>0.063</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>(1) Traditional layout</td>
<td>(5) Importance of VR in space</td>
<td>-0.21 **</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>(1) Traditional layout</td>
<td>(6) Enhancement of classroom functionality</td>
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<tr>
<td>(2) Limitation in class layout</td>
<td>(3) Design stages</td>
<td>-0.497**</td>
<td>0.000</td>
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<tr>
<td>(2) Limitation in class layout</td>
<td>(4) Importance of</td>
<td>-0.407**</td>
<td>0.000</td>
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<td>(2) Limitation in class layout</td>
<td>(5) Importance of VR in space</td>
<td>-0.681 **</td>
<td>0.000</td>
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</tr>
<tr>
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<tr>
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<td>(4) Importance of</td>
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<tr>
<td>(3) Design stages</td>
<td>(5) Importance of VR in space</td>
<td>-0.184**</td>
<td>0.018</td>
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<tr>
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<td>(6) Enhancement of classroom functionality</td>
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</tr>
<tr>
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<td>(5) Importance of VR in space</td>
<td>-0.273**</td>
<td>0.000</td>
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<tr>
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<td>(6) Enhancement of classroom functionality</td>
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<td>0.018</td>
<td></td>
</tr>
<tr>
<td>(5) Importance of VR in space</td>
<td>(6) Enhancement of classroom functionality</td>
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<td>0.065</td>
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</tr>
</tbody>
</table>

Table 15: Pair Wise Comparisons for Architecture Dimensions
### Mauchly's Test of Sphericity

**Measure:** MEASURE_1

<table>
<thead>
<tr>
<th>Within Subjects Effect</th>
<th>Mauchly's W</th>
<th>Approx. Chi-Square</th>
<th>df</th>
<th>Sig.</th>
<th>Epsilon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Greenhouse-Geisser</td>
</tr>
<tr>
<td>Architecture</td>
<td>.40</td>
<td>64.10</td>
<td>14</td>
<td>.00</td>
<td>.75</td>
</tr>
</tbody>
</table>

**Table 16: Mauchly's Test - Phase I**
<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>Variance</th>
<th>Std. Deviation</th>
<th>N of Items</th>
<th>Cronbach's Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantage of Technology in Classroom</td>
<td>20.07</td>
<td>4.55</td>
<td>2.13</td>
<td>5</td>
<td>0.72</td>
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<tr>
<td>Possibility of AR Feature in Classroom</td>
<td>19.80</td>
<td>3.68</td>
<td>1.91</td>
<td>5</td>
<td>0.70</td>
</tr>
<tr>
<td>AR Optimize Use of Space</td>
<td>8.53</td>
<td>.89</td>
<td>.94</td>
<td>2</td>
<td>0.76</td>
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<tr>
<td>AR Enhance the Educational Activities</td>
<td>45.50</td>
<td>11.78</td>
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<td>0.75</td>
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Table 17: Reliability Test- Phase II
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Skewness</th>
<th>Kolmogorov-Smirnov Z</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology in classroom</td>
<td>4.11</td>
<td>0.28</td>
<td>-0.16</td>
<td>1.56</td>
<td>&lt;0.05</td>
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<tr>
<td>AR feature</td>
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<td>0.49</td>
<td>1.68</td>
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<tr>
<td>AR enhancement of design activities</td>
<td>4.13</td>
<td>0.31</td>
<td>-0.16</td>
<td>0.66</td>
<td>0.768</td>
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Table 18: Normality Test- Phase II
## Table 19: One Sample T-test Statistics - Phase II

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>t</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology in classroom</td>
<td>4.11</td>
<td>.28</td>
<td>20.03</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>AR feature</td>
<td>3.96</td>
<td>.38</td>
<td>12.77</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>AR to optimize the use of space</td>
<td>4.26</td>
<td>.47</td>
<td>13.65</td>
<td>&lt;0.05</td>
</tr>
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## Pairwise Comparisons

<table>
<thead>
<tr>
<th>(I) Augmented Reality</th>
<th>(J) Augmented Reality</th>
<th>Mean Difference (I - J)</th>
<th>Sig.a</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Technology in classroom</td>
<td>(2) AR features</td>
<td>0.154</td>
<td>0.074</td>
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<td>(1) Technology in classroom</td>
<td>(3) AR to optimize the use of space</td>
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<td>0.135</td>
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<td>(1) Technology in classroom</td>
<td>(4) Enhancement of design activities</td>
<td>-0.021</td>
<td>0.809</td>
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<td>(2) AR features</td>
<td>(3) AR to optimize the use of space</td>
<td>-0.308**</td>
<td>0.009</td>
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<td>(2) AR features</td>
<td>(4) Enhancement of design activities</td>
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<td>(3) AR to optimize the use of space</td>
<td>(4) Enhancement of design activities</td>
<td>0.133</td>
<td>0.304</td>
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**Table 20: Pair wise comparisons for augmented reality dimensions**
Mauchly's Test of Sphericity

<table>
<thead>
<tr>
<th>Within Subjects Effect</th>
<th>Mauchly's W</th>
<th>Approx. Chi-Square</th>
<th>df</th>
<th>Sig.</th>
<th>Greenhouse-Geisser</th>
<th>Huynh-Feldt</th>
<th>Lower-bound</th>
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</thead>
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<td>.05</td>
<td>.81</td>
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<td>.33</td>
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Table 21: Mauchly's Test - Phase II