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# IS AUGMENTED REALITY A NEW PARADIGM IN DESIGN EDUCATION WHEN EDUCATIONAL SUBSIDY DECREASES?

**Yoke-Chin LAI**
Dept of Mechanical Engineering, VIA University College, Denmark

**ABSTRACT**
Augmented Reality (AR) has become a popular tool in education at all levels, ranging from the primary to the tertiary ones. Many AR tools seem to have been developed with the intention to facilitate educators from various disciplines in adopting the AR technology in their teachings. However, the pragmatic of AR application in the product design education remains questionable. A study was undertaken in an attempt to examine the roles that AR could play in the Product Design process. In this study, AR was first introduced to the design students as one of the applicable tools. The students were observed how innovative they were to integrate AR into their open-ended and ill-structured design project. The perceived usefulness of AR was then evaluated through how much in-depth the AR technology was engaged in the solution finding process. The key aspects explored in the study includes the application potential of the AR technique at the various stages of the design process, and the pros and cons of the AR technique in facilitating the design solution finding. The possibility of AR to become an economical, practical and ubiquitous tool, particularly for encouraging constructive learning in the mechanical engineering based product design area will also be discussed in this paper

*Keywords: Augmented Reality, design education, product design, ubiquitous tool, constructive learning.*

## 1 INTRODUCTION

Application of Augmented Reality (AR) into Mechanical Engineering based product design education is yet widespread although the AR technology has gradually matured in these recent years. An elective product design course offered by VIA UC Mechanical Engineering education experimented the practicality of AR technology application to a product design class, in an attempt to study its application potentials through the students' responses and feedback. In this article, the background of the course involved in the study was briefly described. The study set-up, the evaluation method used in collecting and assessing the students' responses were outlined. A conclusion was drawn followed by some discussions upon the synthesized outcomes.

## 2 THE COURSE BACKGROUND

Constructivist approach [1] has been actively adopted in PUD1, which was a 12-week elective course offered to the 6$^{th}$ and 7$^{th}$ semester of Bachelor Degree level Mechanical Engineering students of VIA UC. The key objective of the course was to introduce user-centred design (UCD) practices to the mechanical engineering students who were presumed to have acquired adequate fundamental engineering design skills from their previous semesters. The curriculum framework of the course was organized in two dimensions: 1) the skill and knowledge learned, and 2) the pedagogical approach used.

Project-based active learning was applied in this course. Many user-centred product design skills were explored by the students through their self-directed and actively cooperated and participated team-based design activities, started from design problem framing to solution finding. The students were encouraged to be the owner of their constructive learning settings where their UCD knowledge and skills were continuously learned, practised and testified. This pedagogical approach was believed useful for the students to realise that learning was a continuous, life long process results from acting in situations [1].

# 3 THE STUDY SET-UP AND METHODS

Prototype making and testing are key elements in a product design process. Producing a user interact-able prototype was emphasized in the whole PUD1 course. In the first three weeks out of the 12 weeks lessons, the students were introduced the key principles of UCD followed by a few user's needs discovery methods/tools, including interviews, contextual design inquiry, observations, empathy map, repertory grid techniques. Students were free to decide the prototype nature (e.g. full-sized vs. scaled, full vs partial functional, etc.) based on their personal preference, prototype construction skills, prototype material accessibility, economy budget and time, etc.

In the 4$^{th}$ week, as the first stage of the UCD project, the students were required to define an explorable design problem area based on the inspiration gathered from their surroundings. To kick off the UCD project, the students were assigned an exercise to generate digital 3D models of ubiquitous and/or household products. Due to limited budget in economy, the digital 3D models generation was conducted with some free photogrammetry scanning apps. The generated 3D models were then uploaded to an Augmented Reality software (free demo version). The objectives of this exercise were 1) to introduce the students some free tools applicable for generating digital 3D models and AR scenes; and 2) that AR-based 3D models (hereafter referred as AR representations) could serve as an alternative communication media through which user's needs and affective responses could be more efficiently stimulated and then uncovered. A design problem area were better defined only if the user's actual needs could be identified. Apart from functionality and usability, affective need has been proven a crucial tacit entity that needs to be considered for a successful product design [2][3].

Before proceeding to the conceptual design stage, the students continued the project by eliciting user's needs using a wide of range of methods, among these were interviews, observation, and repertory-grid-technique. The solution space exploration initiated from idea generation where as many solutions to the problem area as possible were generated. Some conventional techniques such as hand sketches, morphological chart, SCAMPER were usually adopted for this purpose. 3D CAD modelling was also found used by some students at the idea generation stage. Usability evaluation techniques instructed in the course were then applied in order to evaluate each of the generated ideas from various perspectives including functions, usability, safety and aesthetic.

# 4 AUGMENTED REALITY (AR) APPLICATION - WHERE AND HOW

Problem recognition was the first but key stage in the Problem Analysis phase (see Figure 1), as conforming to the PUD1 course objective, that it was crucial to have the students trained to be sensible to their surroundings. Seven groups of 3-4 students were formed. Each group created AR-models (or AR representations) of three different ubiquitous products, for instance those of the household category (e.g. electric kettle, can opener, shelves, etc.). The AR representations were visualized through mobile phones, handheld devices or on personal computer to avoid the extra expenditures on Head-Mounted-Devices. Each group ran a product analysis session based on their interactions with the AR representations in order to brainstorm the strengths and weaknesses of each product. A synthesis matrix was a tool used later in an attempt to organize the brainstorming outcomes, which would form the basis in recognizing a problem area for further exploration.

The user's needs discovery stage initiated after a problem area was defined but remained ill structured. The students were required to use 1) ordinary interviews followed by 2) repertory-grid-technique interviews on at minimum 5 users of some products that were relevant with the defined problem area. Observation could be used as a supplementary but not mandatory. The interview method served as the "control" method. The outcome generated from the interview method formed the baseline data for later comparison with that obtained from the repertory grid technique.

Contrarily to the conventional repertory-grid-technique interviews, instead of photos or physical objects, AR-representation were used throughout the session in an attempt to stimulate from the interviewees the use-experience corresponding to the products shown in AR representations. Using AR representations was reported positively for stimulating the use-experience and emotional response and thus could facilitate the user's actual needs capturing [4]. In the solution-finding phase, option was given to render the 3D digital prototypes into AR representations so that these prototypes could be proceeded to test. A proper planning on the test scenarios and setting was of particularly essential when AR-based prototypes were to be used.

## 5 RESULT

Each student group was required to fill out an empathy map (see Figure 2) for expressing their use-experience with respect to AR technology application in the relevant design stages, namely the problem recognition, needs discovery, prototype build and test, respectively, as that highlighted in Figure 1.

In the problem recognition stage, 4 out of the 7 student groups succeeded the AR-models generation assignment with moderate satisfaction. The rest showed low satisfaction due to one primary reason: the quality of the 3D models generated with the free photogrammetry scanning App was too low for pragmatic implementation in the AR setting.

Positive responses were obtained about the use-experience stimulating roles played by the AR representations in repertory-grid-technique interviews. In comparison with the traditional interviews, all student groups reported the user's opinion uncovered in AR supported repertory-grid interview was more insightful. The preparation of AR representations for the interview purposes was however commented too labour intensive and time consuming.

In the prototyping stage where prototype making and testing were involved, only 3 out of 7 student groups conducted an AR representations supported prototype test session. The AR-based prototype test session provided merely visual interactions to the testees. The visual interaction was commented useful when the proportion of the prototype actual size to the real-life setting/environment was concerned.

A synthesis matrix shown in Figure 3 was constructed in an attempt to summarise the empathy map data compiled from the 7 student groups.

## 6 DISCUSSION

It has been a challenge for UCD educations that the importance of prototyping shall be emphasized while the subsidy for the prototype making materials were substantially reduced. 3D print has been a popular prototyping option in these recent years. However, the supply-demand inequality developed by this option has become a constraint in the VIA UC Mechanical Engineering Department.

Introducing some other alternatives could be essential for continuously cultivating the prototype making and testing practices in UCD education. Augmented Reality, a maturing technology, has demonstrated various potentials in many educational disciplines [5] [6] [7]. Is AR technology sufficiently mature to contribute a change in the prototyping paradigm of UCD education where user-product (or user-prototype) interactions are of importance? The following paragraphs will summarise the satisfying and dissatisfying aspects that could form the implication basis for the student acceptance of AR technology as a ubiquitous prototyping tool/method of UCD educations

As highlighted in the CDIO [8] aligned UCD education framework (see Figure 1) applied in PUD1, problem recognition, needs discovery and prototype test were the three key design stages in the conceptual design phase investigated in this study. The purpose was to examine the pragmatism of applying AR as a ubiquitous prototyping tool and how early in the conceptual design phase that the deployment of AR-based prototype would be beneficial. To meet the purpose, the AR technology was only applied using either a handheld device (mobile phone or tablet) or personal computer, and with the minimum investment on AR relevant software and apps. Through constructing a synthesis matrix, the students' use-experience and emotional response stimulated from AR-based prototype application was analysed in an attempt to realise the insights in the relevant aspect as delineated hereafter.

Based on the students' feedback, it was too time consuming and labour intensive to prepare AR deployable 3D models with photogrammetry 3D scanning method, particularly at the early stages wherein many AR representations were applied as communication media with the targeted user group. One of the key features of prototype is to have short development time. A prototyping method that demands excessive development time will contradict with this feature. However, from the economic perspective, the photogrammetry scanning method was relatively cost effective comparing with that of 3D scanner, in particular when free app was available.

The level of accuracy (or fidelity) attained by the AR representations varied with the method chose to create 3D model, amongst them were photogrammetry scanning, 3D scanner or CAD modelling. The photogrammetry scanning method was although easy to access and cost free, creating a 3D model that was with satisfactory level of fidelity was somehow a challenge. 3D model created by 3D scanner characterized features including higher quality in terms of the level of fidelity and more time efficient in creating. Time/labour, cost and level of fidelity were therefore the contradicting factors to the success of AR-based prototype/representation.

The level of interaction demanded from an AR-based 3D representation is dependent on what type of information is planned to collect through the representation and at which design stage the representation is deployed. At the problem recognition and needs discovery stages, the AR-based 3D representations played the use-experience stimulation role so that better communication between the targeted user and designer could be achieved. This early design stage communication was crucial for a designer (i.e. the student groups) to proper outline a problem area after pinpointing the user's actual needs. AR-based 3D representations, although only visual interact-able, were reported useful by 60% of the student groups in discovering the insights to opinions and experience in product use, particularly when the AR representations were deployed in conjunction with the method of repertory grid interviews. The AR representations was effective because the 3D models could be viewed in their actual sizes while being augmented into the real-life environments. This feature of the AR representation was commented active communication stimulating, particularly obvious during the experience sharing session of the repertory grid interview. This was because by using AR representations as probes, the interviewees were noticed able to easier recall their memory about the product of concern, and to better describe and express their feelings about the product.

Prototyping is one of the essential steps of participatory design, and is therefore crucial in UCD education. In order to elicit the user's actual needs with respect to the behavioural, reflective and visceral aspects [2], user-prototype interaction has been affirmed essential for prototype evaluation. Producing a prototype that could enable user-prototype interaction would therefore be essential. A full or partially functional prototype will serve well in this respect if direct manipulation on the prototype is possible through various sensory interactions, including visual, auditory, smell, and haptic.

The AR representations created and used by the student groups demonstrated to some extent some positive implications from the visual-interaction perspective. These AR representations permitted visual explanatory to the prototype testees but with limited or nearly zero tactile feedback. Due to the tactile-interaction limitation, the evaluation on the usability and functionality aspects of the prototype was immensely restricted. This situation has limited the potential of an AR-based prototype to elicit the user's opinion about the functionality and usability of a product design idea. Furthermore, the lack of haptic interactions was commented exhibit the weakness in constraining the intuitiveness of prototype to the testee. For testees who were lack of technical knowledge/experience in the AR area, confusion was noticed arose in their attempts to physically interact with the AR-based prototypes. The shortcoming with respect to tactile feedback may however be improved with the integration of some haptic devices, which vary in different price range dependent on the technological complexity behind.

# 7 CONCLUSION

To conclude, the student acceptance of AR-based prototypes in UCD education will depend on the following criteria: a) quick to produce; b) easy to produce, use, interact with and amend when necessary (low technological complexity, low learning curve); c) economical (no additional expenditure); d) effective (will allow them to achieve the purpose of prototype). From the experiential point of view, the current cost free AR applications and authoring tools exhibit low technical maturity for non IT-based students to manipulate for achieving the satisfactory prototyping purposes. If the investment on the relevant software and supporting hardware is to be kept minimal, the pragmatic aspect of AR application in design education, particularly in prototyping, has yet implied profound impact to a paradigm change. AR applications however demonstrated some positive values in providing an innovative collaboration environment for a more effective communication of opinions and affective responses with respect to a product and/or design idea.

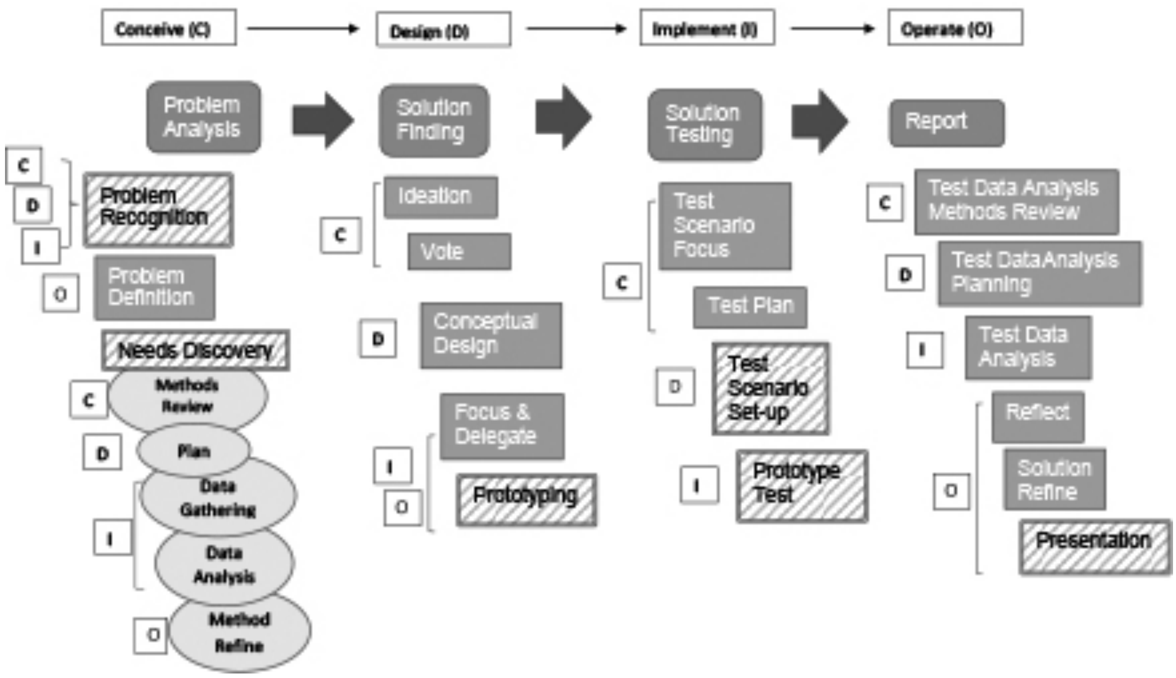


*Figure 1. Design stages that adopted AR applications. Alignment with CDIO framework*

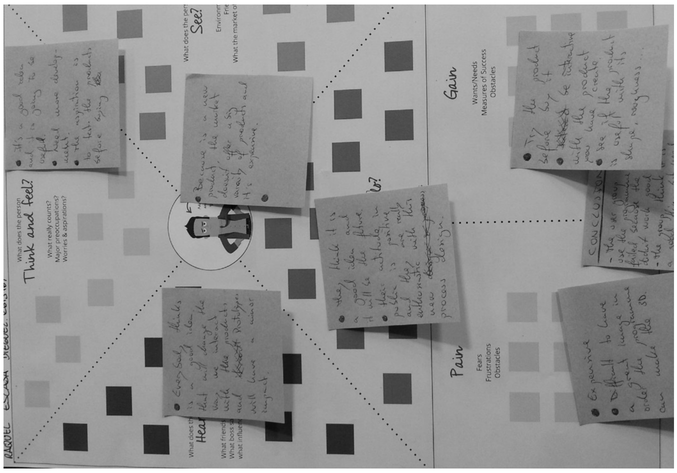

*Figure 2. Example of Empathy Maps filled out by a student group*

| | Problem Recognition | Needs Discovery | Prototype Test |
|---|---|---|---|
| Think and Feel | - Time consuming<br>- Labour intensive<br>+ the actual size in the room reminds us of his weaknesses or strengths | + AR models helped to remind the interviewee of their opinions on using a product.<br>- Testees would like to feel/touch the AR models but could not. | - Too labour intensive to make file format conversion<br>+ inspire the aesthetical value added by a new design to the relevant surrounding. |
| See | - Most of the 3D models generated could not represent the real products.<br>+ potential of creating 3D models with photogrammetry scanning app. | + Testees enjoyed rotating the models trying to interact with them. | - The non-texture-rendered 3D models were not appealing.<br>+ could estimate the space required. |
| Say and Do | - Too much time spent.<br>- Use 3D scanner instead of photogrammetry scanning app could make better quality 3D models.<br>+ Free app<br>+ Free AR softwares (demo version) | -Tedious to create many different models as the interview preparations.<br>- Use 3D scanner instead of photogrammetry scanning app could make better quality 3D models.<br>+ Free app<br>+ Free AR softwares (demo version | - Need 3D Studio Max or Blender for better texture rending.<br>- File conversion is tedious. |
| Hear | + Supplement restaurant menu with AR models created positive responses | + Supplement restaurant menu with AR models created positive responses | + visio-haptic interactable AR models function as well as the full scale, full functional prototypes.<br>+ visio-haptic interactale AR models are more economical |

*Figure 3. Synthesis Matrix of Empathy Map Compilations*

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