Experiencing new Learning, Interaction and Visualization Process using Augmented Reality Technology

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***Abstract* – Many learning methods have changed the way students learn. One method that is achieving much attention is augmented reality (AR). AR is a technology that blends simulated and real environment during the learning, interaction and visualization process. This study explores how far AR technology has come to support students in their learning and interest in using this technology. The objective of this paper was to determine the usefulness of multiple markers interaction user interface for an AR application. A hands on practical lab was conducted with first year engineering students at UNITEN. Two AR applications were tested by the students using single marker and multiple markers for interaction. The opinions and preferences regarding the two user interfaces (also known as tangible user interface) that can be used for problem solving activities was obtained. The first AR application using single marker comprises two markers to interact with the problem presented. The second AR application using multiple markers on a single paper was used for the same purpose. These two operationally equivalent user interfaces were given to selected students to interact with the AR applications. During the hands on practical, data were collected regarding the student's preference, effectiveness (attractive) and easy-to-use. The quantitative and qualitative analysis which followed, indicated that the multiple markers user interface was more preferred, effective and easy to use.**

***Keywords* – Augmented Reality, user interface, interaction, tangible, modelling.**

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1. Introduction

The revolution in computer interfaces has changed the way humans think about computers. Computer technologies have been introduced to educational settings and have made learning a more flexible and intuitive activity [1]. Among these technologies, augmented reality (AR) drew huge public attention because it provides a new perspective for learning by allowing learners to visualize complex spatial relationships and abstract concepts [2] & [1].

One branch of ICT i.e. Augmented Reality (AR) is drawing considerable interest not only because it involves novel or "cool" technologies, but also because it promises to help users manage information overload. As opposed to multimedia and virtual reality (VR), AR helps present information succinctly, in its "*natural*" home, where users can easily benefit from and act on it [2]. AR presents a view of the real, physical world that incorporates additional information (such as 2D/3D virtual objects) to augment or render this view. Although AR has been studied for over forty years, it has only been recently that researchers have begun to formally design and evaluate AR applications particularly on its user interface and educational benefits.

Most of the published AR research has been on enabling technologies (tracking, displays, passive visualization), or on experimental prototype applications, but there has been little user evaluation on AR interfaces [3]. Additionally there is little empirical evidence on its effectiveness of use in education.

One reason for the lack of the abovementioned evaluations in AR could be a lack of knowledge on how to evaluate AR experiences, how to properly design experiments, choose the appropriate methods, apply empirical methods, and analyze the results. There also seems to be a lack of understanding of the need of doing studies or sometimes the incorrect motivation for doing them. If user evaluations are conducted out of incorrect motivation or if empirical methods are not properly applied, the reported results and findings are of limited value or can even be misleading. One of the interactions that bridge the user and the 3D environment is a marker or symbol that is used to recognize the virtual model on screen. This sort of user interface is also known as tangible user interface (TUI). However, a problem that hampers such a user interface is that each marker may be used for a specific function. If the application has five or six functions to perform, the user have to change each marker to see the result of each function. This scenario makes the user spend too much time on the interaction process rather than visualizing the problem. In this research, the evaluation of novel AR engineering applications are designed, tested and evaluated by potential users of the application. The results revealed that the new user interface i.e. interactive paper with multiple markers capability provided a better and more natural interaction as compared to the single marker based application and stundents could focus more on visualization rather than interacting with the application. This study investigates first year engineering student"s preferences of using two AR applications, namely a single marker and multiple markers. The objective was to measure students" opinions and preferences regarding the experience with both the interfaces. More specifically, data regarding student"s preference, effectiveness and easiness-to-use were recorded and analyzed. The next section describes the literature review of AR technology and applications followed by the design of the use interfaces, evaluation methodology, results and conclusions

2. Background on AR Technology and User Interface

Augmented reality that employs tangible user interface has the advantage of engaging a user in the learning such as interactivity and simulation. According to [4], AR is a technology that "offers a new educational approach in helping learners to develop critical capacity and deeper understanding of the concepts underlying scientific investigation". It allows learners to interact with the real and virtual environments and manipulate objects that are not real. Since the AR technology is changing the face of education today, whereby users can learn in a more creative, interactive and appealing manner, we chose this technology and designed a new user interface platforms to test its usefulness with our students. The aim of this study was to improve mechanical engineering student"s knowledge on the multibody (four bar linkages) problem. From the past experience, most lecturers who have taught this subject found that some students could not relate the theory learnt, thus were unable to visualize the effects and changes of the mechanisms.

As for the user interface, since the use of computers and operating systems, many user interfaces have emerged from command driven, graphical user interfaces (GUIs), touch screens to voice recognition. However, AR technology introduced a new type of interface, i.e. Tangible User Interface (TUI). Years ago, a lot of research has been done on moving the user interface out of the screen and into the physical environment of the user (Figure 1.) or as stated by [4] "*to change the world itself into an interface*".

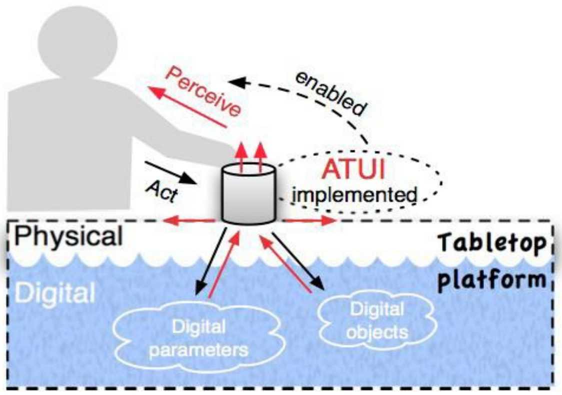

Figure 1. Definition of tangible user interface

The interest in TUIs has grown constantly every year as more tangible systems are being implemented. The term "Tangible User Interfaces" signifies systems that allow the user to interact with the computer through physical objects (other than mouse and keyboard). For example, InfrActables is a table with back projection collaboration and it also permits interface by using TUIs that incorporate state detection [5]. Other findings reported that the use of InfrActables added different buttons to the TUIs that allows added functions related to the TUIs [6]. Subsequently the term "Augmented Reality" was originally meant to cover a wide variety of approaches used to develop the TUIs [7]. Since [8], vision of ubiquitous computing two decades ago, many research efforts have been made to move computation into the real world out of the workstation. One such research area focuses on "*Tangible User Interfaces*" or TUIs (those that provide both physical representation and control of underlying digital information). The idea with TUIs is to have a direct link between the system and the way the user controls it through physical manipulations by having an underlying meaning or direct relationship which connects the physical manipulations to the behaviors which they trigger on the system. Since then TUI has been viewed by many researches as an alternative to GUI.

Tangible Augmented Reality (TAR) is a combination of an Augmented Reality (AR) System and a Tangible User Interface (TUI). A user interacts with virtual objects by manipulating real objects. In the normal practice, there is no need to learn one of the common 3D interaction techniques because the interaction with virtual objects is done in the same way as the interaction with real objects. Since the existing interaction of AR with the virtual object is via markers (a tag/symbol to recognize and display a particular object on the display) which allows users to perform a single function at a time, in our new design and approach, we allow the user to perform multiple functions. This is explained in more details in section four of this paper. In short, the two most debated interfaces to be the ideal interfaces of the future are the convention Graphical User Interfaces (GUI) and Tangible User Interfaces (TUI). GUI is driven commonly by Windows, Icons, Menus and Pointers in a desktop environment while TUI is generally driven with tangible/tactile interaction devices in most AR realms.

The principles of user interface design have been studied by many researches [9] & [10]. Some researches deduced that user interface design should be focused on structure, simplicity, visibility, feedback, tolerance and reuse principles [11]. However most of these methods to develop sound design principles are appropriate for user interfaces with graphics, but they could not be fitted properly for latest technologies, e.g. environments of virtual reality or augmented reality. As such, the two most debated interfaces to be the ideal interfaces of the future are the conventional Graphical User Interfaces (GUI) and Tangible User Interfaces (TUI). In this research the TUI design method was chosen because the main principle of design include; physical controllers for transferring virtual content, time and space multiplexed interaction, support for spatial 3D interaction techniques, support for multi-handed interaction, match object affordances to task requirements, support parallel activity with multiple objects and allow collaboration between multiple users [12].

3. AR Architecture

Figure 2. shows a conceptual reference architecture for an AR application, including its essential components and some image-related annotations as examples [2]. AR could potentially apply to any sense, including hearing. A reality sensor (camera) observes a part of the reality. It then passes the image it obtains along with metadata such as geolocation tags to the trigger matcher, which checks if its input matches the relevant application specific trigger. Such triggers could include geolocation that‟s near a specific landmark or the image showing the landmark.

The trigger matcher then produces matched metadata, such as the image‟s semantic category and outline. The augmentation selector takes the matched metadata from the trigger matcher and retrieves relevant information, such as the year the landmark was built. It constructs an augmenting image, such as a text bubble or a map pin that can be placed relative to the original image, and passes it to the reality augmenter, which combines the images and renders them for the user. The same structure would apply if we think not of images but of video streams. And the architecture would often be enhanced with other modules to more naturally determine what element of the scene is most relevant to a user and how a user could interact with the augmented view for example, by tracking the user‟s gaze [2].

Since we mentioned earlier in this paper that usability is one of the core challenges in designing AR based applications, this has to be carefully devised as AR faces the same usability challenges as traditional interfaces. For example the potential for overloading users with too much information and making it difficult for them to determine a relevant action [2]. Therefore, designers should focus on several key questions to address usability concerns such as "*Can the user interact with the virtual object naturally?*", "*Can the user focus on the contents being interacted with?*", "*Is the augmentation align with reality*?" and "*Can the user gain enough of information from the AR application?*" etc.

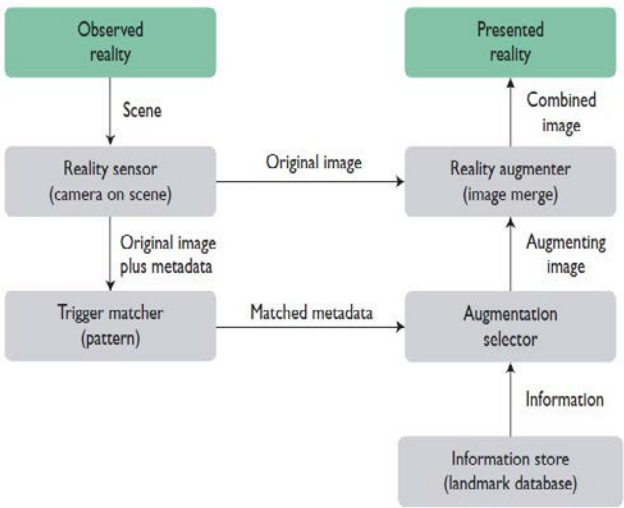

Figure 2. Conceptual architecture of an augmented reality app [2].

4. Comparison Studies Involving AR Interfaces

A limited number of studies have attempted to clearly compare the use of AR interfaces to that of a graphical equivalent. These studies and their results, which are briefly presented below, strongly emphasize the need for further research in the field.

Despite many claims by previous researchers that TUI is better than GUI in terms of usability, most carried out experiments on computer-literate subjects or without taking into considerations their possible prior computing experience. For example [13] presents the results of an exploratory comparative study which investigated the relationship between three different interface styles, and school-aged children‟s enjoyment and engagement while doing puzzles. The researcher [13] compared TUI, GUI and the physical (traditional) puzzle interfaces. The research suggested that there were no significance differences in terms of enjoyment for all three interfaces. Another researcher [14] studied comparatively a physical versus a graphical interface in a Piagetian balance beam task. The task involved adults and addressed the assumption that manipulations of physical artifacts have cognitive influences on learning. The study did not find any differences between the two conditions. The researchers finally concluded that, because of the statistical limitations of the study (e.g., small samples), it is not possible to conclude whether an effect of physicality in the specific task there exists. However, further research was proposed, engaging also younger participants.

An interesting study was also carried out by [15], comparing a tangible and a multi-touch interface activity based on logistic problem tasks. The scope of the task was to investigate whether the physicality of the TUI has an impact on the performance, collaboration quality and learning benefits in the specific domain. The results provided evidence of an increase in collaboration quality and playfulness of the task. Also, the tangibility of the system helped to increase exploration and by this means to enhance performance and learning. Another research [16], performed a comparison study between real and a combination of real–virtual electronic circuits. The research by [16] presented evidence that the students‟ conceptual understanding of electronic circuits was enhanced at the real–virtual experimentation condition, more than merely with real experimentation. A human computer practitioner [17] highlighted the impact of graphical user interface (GUI) and Tangile User Interface (TUI) on students with no prior computing experience in terms of engagement measures. The study found that TUI was efficacious in elevating the students‟ learning performance, and motivation. Further research and data analysis showed that the replacement of real experimentation with the virtual in the experimental group had positive influence on student learning.

The motivational hypothesis of this present study is rooted on two assumptions. First, single marker user interfaces being „„„natural‟‟‟‟ allow physical manipulation which is experienced as more enjoyable by students as compared to a graphical interface (the common windows screen like interface). Second, multiple markers interface allow easier accessibility, and consequently, allows more focus on the learning material contents. Accordingly, the research questions that this study explores focus on how the students of various backgrounds, who have used both the AR applications under study, evaluate the following interface qualities:

1. Preference (which interface did the students liked more?),
2. Effectiveness (which interface was on focusing on the contents?) and
3. Easiness-to-use (which interface was easier to use?).

The above measures were operationalized by the corresponding responses in a specially designed questionnaire and were used as dependent variables in the subsequent statistical analyses.

5. 4BL Problems and Concepts

The AR application for visualizing engineering concepts allows the student to relate the real object (in this study four bar linkage mechanism) with the technical information. The objective of this work was to study and understand the motion of the 4BL (bar link) mechanisms and see how it could be simulated [18]. The purpose of this mechanism is to transmit motion and force from one location to another. The theory of this mechanism can be understood by the 4BL (which consists of four rigid bodies each attached to two others by single joints or pivots to form a closed loop) [23]. The types of four link bar linkages that are possible to be modelled by the system based on the user input can be shown in Figure. 3.

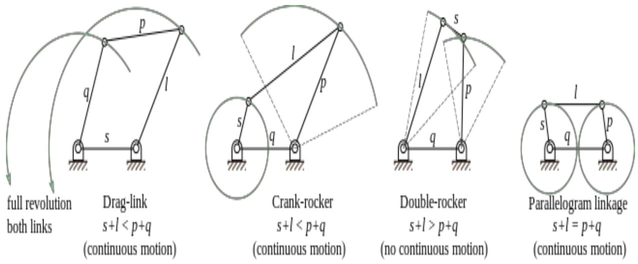

Figure 3. Types of four-bar linkages, s = shortest link, l = longest link

The possibilities for the input and output links for the linkages could be assumed as following:

- *A crank: can rotate a full 360 degrees*
- *A rocker: can rotate through a limited range of angles which does not include 0° or 180°*
- *A 0-rocker: can rotate through a limited range of angles which includes 0° but not 180°*
- *A π-rocker: can rotate through a limited range of angles which includes 180° but not 0°*

Four-Bar-linkage mechanism can be found in many applications such as Human body, Automatic Windows and Doors, Crane movements system in heavy vehicles etc. In our point of view and in general we can say any mechanical device can have a 4BL mechanism connected with other mechanisms. In theory, students could be posed with some typical questions such as 1. How many links are there in the mechanism, 2? How many joints are there in the mechanism and their types, 3? What are the relations between the links and joints, 4? What are the fundamental dimensions of the links to achieve the desired motion? 5. What are the actual shapes of the mechanism which can provide enough strength and stiffness during the motion? It is clear that this sort of problems may require several attempts for the student to try and understand before the problem could be solved. Further explanation on this problem is given in [19]. Most simulation of 4BL mechanisms that are available at present are designed using 2D graphics which may not be appropriate for visualization process [20]. In addition the workings for the solution of a given problem are not shown in details thus leaving the student to work on their own to understand. In our approach the student is able to interact with the 4BL mechanism in a real time 3D environment and is able to experiment the parameter updates of the animated 4BL by inserting different values that meets grashofs law. In addition the simulation tool fully functions as an engine to solve the problem by showing all the steps with the final answer.

6. The Design Approaches of The User Interfaces

In this research, we employed two design approaches to model and design the bar linkage mechnisms interface. The first design was a single marker based interaction and the second design was a multiple marker based interaction. A snapshot of the marker based AR application is shown in Figure 4. and the multiple markers based interaction is shown in Figure 5. The interactive multiple markers interface is also shown in Figure 6. at the top left hand side. In this design, seven basic functions were implemented for the user to interact with. For example, a symbol could be touched to change the color of the four link bar or to hear some explanation. The pipeline flow chart of the application is shown in Figure 6.

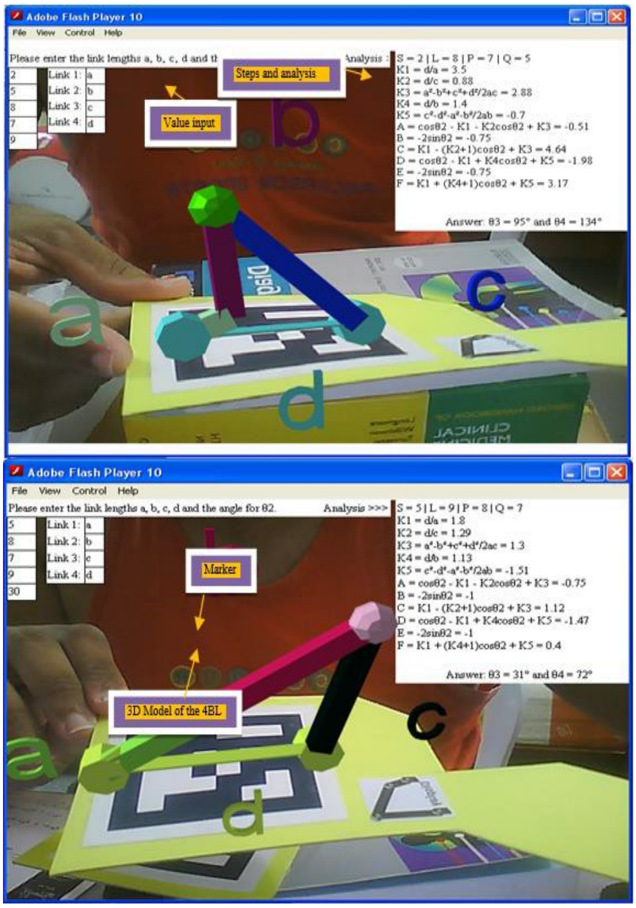

Figure 4. Single marker based interaction and simulation

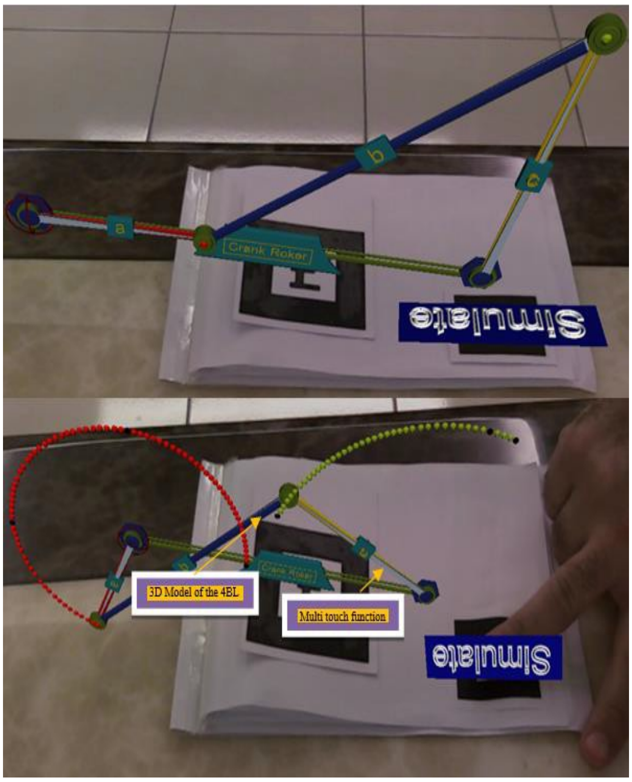

Figure 5. Multiple markers interaction and simulation

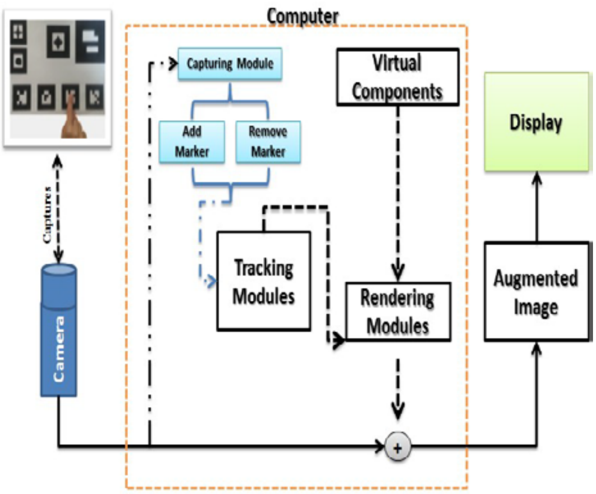

Figure 6. Pipeline flowchart of the application

According to Figure 6., the main procedure in most AR applications is to capture video from the webcam as a first step. The AR software then has three main algorithms to apply i.e. (Recognition, Tracking and Rendering). In the recognition phase, the recognition algorithm searches for a "Target or Marker" in the video stream, which can be either a single (Target or Marker) or a group (Target or Marker). While in the tracking and rendering phase, the tracking algorithm tracks the target and imposes a 3-D overlay by adding a virtual object, before rendering it back on the screen in real time.

However, in our approach we do not use single markers as the interaction mode, instead we implemented all the functions on a single paper whereby the user does not have trouble in holding and interacting with the multiple markers to perform different functions. To achieve the functionality, all the user needs to do is to touch on a particular function marker on the paper with the finger to start the simulation and touch the stop function again to stop/pause the simulation as shown on the right in Figure 6. This could be continued again by touching the start button on the paper as shown in the same figure. This new method of tangible user interface has significantly contributed to the innovation of a new type of user interface and could help learners/users to focus more on the problem rather than using single markers and spending more time in the interaction process. Our new multiple markers‟ user interface is now being extended to eight interactive functions as shown in Figure 6. In this user interface, the user is able to approach the problem by touching the symbols shown on the paper for example to change the color of the linkages, to start/stop the animation, while computations of the 4BL linkages which are done in real-time.

7. Application Testing Method with Subject Matter Expert

Regular testing of the developed applications were conducted with the subject matter expert, in this case the lecturer teaching the subject. Major testing include; obtaining the correct rotation of the mechanism and solving the kinematic equations correctly.

Algorithms were developed and tested using programming code to check that the system generated the results as expected as the ones obtained by hand calculations. The AR application was capable to simulate all types of the designed mechanisms (Crank Rocker, Drag Link, Double Rocker and parallelogram Linkage).

The developed approach of how to interact with the simulated kinematic models were structured based on the learners need. First step is, the learners need to understand the concepts of 4BL; the simulation environment gives the learners the ability to pass the required parameters to simulate the 3D model and visualize it in the real time environment.

The second step is, the need of improving the visualization process of the kinematic models. This aspect has been dealt with; by using the single marker as a tool to display the kinematic model, this gives the learners the ability to view the model from different directions (Top view, Bottom view, Left view and Right view). Another marker is used to start/pause the rotation of the kinematic 3D virtual models.

The third point is the learners need to study the kinematics of these simulated models and analyze the results that come from equations / calculations; for this task the simulation provide learners with continuous calculation (every degree of rotation) of the model equations. At any instant of time, learners can pause the simulation in order to study any particular status of the model. To evaluate the previous tasks, an experimental study was conducted for this purpose as discussed in the following section. Testing of the problem domain and confirmation of the effectivess of the new user interface was conducted at the computer aided learning multimedia software lab at UNITEN by a human computer interaction expert (HCI). The results of the HCI expert on this study is presented elsewhere since this study only takes into account the students‟ opinions on preferences, effectiveness and easiness-to-use.

8. Procedure, Results and Discussion

The subsequent sections describe the approach taken in evaluating the 2 user interface design for visualizing the engineering concepts on the four link bar mechanisms.

8.1 Participants

The study was conducted during the first semester period (2016) at Universiti Tenaga Nasional (UNITEN). Thirty-two undergraduates taking the first year mechanical engineering course participated in the study.

8.2 Setting

Practical experiments were conducted in a computer lab with six groups of students (Figure 8.). Six computers were adequately arranged with 4 groups comprising 5 students to a computer and another 2 groups comprising 6 students to another 2 computers. The interview and the completion of the questionnaires were conducted in the same lab, always in visual contact with all the computer systems.

8.3 Design

This study explored quantitative data by means of statistical tests by implementing a two-way ANOVA. The dependent measures of the study are students‟ preferences (SP), effectiveness and easiness-to-use. The study had three distinct phases: recording of the participants‟ profile, interaction with single marker application, and interaction with multiple markers application, free sequential interaction with both systems and completion of the questionnaires. In addition, data from observations and interviews were analyzed.

The hands on practical lasted about 1 hour (this includes explaination by the developer on how to use the AR applications). The students, guided by the researcher and academic staff, first filled out the questionnaires about their course, IDs, familiarity with computers and the use of problem solving software.

Then, the single and multiple AR markers application was presented and the researcher asked them which of the two user interfaces they would prefer to use in order to interact and visualize the 4BL problem. The answer to this question was recorded as the preference towards the most preffered application of the two.

Following a simple scenario, the researcher presented to the students how they could interact and use the markers for both applications. After the end of the presentation, we asked the students to declare which system they preffered the most. This was the first measurement of the preffered variable.

8.4 Qualitative Data Collection Methodology

Qualitative data were collected employing a twofold methodology approach: (1) structured observation and (2) student interviews. All data were collected by the AR applications developer in the form of observation notes. In detail:

(i) Structured observation: while interacting with the user interfaces, two researchers collected data that emerged from student‟s interaction. Data were obtained: (1) from the discussions between the students, (2) personal observations that focused on the difficulties that the students faced.

(ii) Interviewing: after completing their questionnaire, students were interviewed on their experience (semi structured interview). Our main effort was to validate and better understand the data collected from the questionnaire and the observations. So, students were asked to give further details about their experience and comment on the points we believed needed clarification. These data being correlated with previously recorded data offered opportunity for confirmation and fine-tuning of the resulting conclusions.

8.5 Quantitative Measurements

Three dependent variables operationalizing students‟s subjective viewpoint on the two systems were measured, namely preference (the most liked user interface), effectiveness (user interface that helped them to focus most on the contents) and easiness-to-use (the easiest user interface to be used). In this method, the answers are double checked in order to enhance reliability. In the self design questionnaire, based on the sample questionnaires designed by [21] were given to students to tick their choice in a three-point Likert-type questionnaire. This way the students declared, for example, which system was the most preffered and which the least and if the single marker or multiple markers application was very easy, easy or little easy-to-use.

9. Results – Quantitatve Analysis

Table 1. presents the percentage frequencies of the students‟s preferences regarding the single marker application and multiple markers application interfaces. For the entire sample, the multiple markers‟ application was more likely to be selected as the students‟s preference (however without statistical significance), while it was characterized as more effective and easier to use (both statistically significant, p<0.01 and p<0.05, respectively).

Table 1. Percentage frequencies of student's references between the two user interfaces

	Multiple markers	*Single marker*
Preferences	64.1	35.9
Most effective	78**	22
Easier-to-use	62.2*	37.8
*** p<0.05; ** p<0.01**		

9.1 Preference/Effectiveness Variable

As expected it was found that students showed statistically significant higher preference for the multiple markers interface (x^2 = 4.22, p<0.05). Effectiveness was measured at two successive points in time: (a) before direct interaction, and (b) at the end of all hands on practical session. During the practical testing, preference is higher for the multiple markers interface and these differences are statistically significant with chi-square (p<0.05) in all cases except effectiveness for the group that used single marker based interaction.

9.2 Ease to use Variable

The analysis of students‟ responses to the elements asking which interface was easier to use revealed an motivating effect. The mutiple markers interface was found to be easier to use for the students and this effect is changing with technological enhancements. Figure 7. depicts the effect, which is statistically significant, (Cramer‟s V = 0.64, p<0.0001). Since these effects on multiple markers interface were measured comparatively to the single marker interface, any positive or negative changes across the categories of the independent variables could be considered as negative or positive changes, respectively, for the single marker interface.

9.3 Observation and Interviews

From our observation and interviews, both applications worked very well and helped students to successfully learn, interact, visualize and complete the problem solving tasks on the 4BL mechanisms. The assigned tasks were on purpose selected to be easily accomplished by the students, within the available time, so that they were successful and satisfied by the outcome. Indeed, the goal to complete successfully the problem solving process was satisfied for all the students and conditions. All the students seem to be attracted to see the new augmented reality applications and were engaged with the problem solving tasks. The students, particularly during the free interaction period, showed high interest to learn all the available commands and features of the applications.

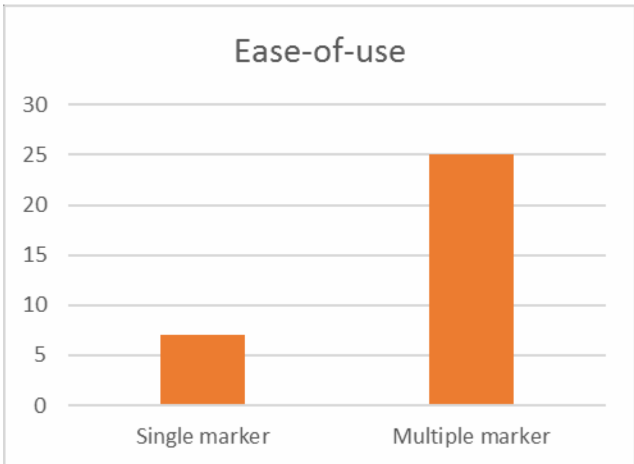

Figure 7. The easy-to-use variable for single and multiple marker interface

10. Discussion

In this paper, we used two approaches in designing and interacting with augmented reality applications, namely single and multiple makers interface to study comparatively students‟ preferences regarding the use of such interfaces to solve 4BL problems. This comparison involved three dependent variables, namely preference, effectiveness and easiness-to-use. The results showed how the above variables might be varying by student‟s preferences of the two applications, when they interacted using the interfaces under investigation. Our aim is to make a contribution to the ongoing investigations on augmented reality based applications and inspire researchers to further explore specific contexts in problem solving activities for students of higher learning institutions.

10.1 First-sight-preferences

Student‟s preference, which can be considered as a measure of the desirerability of the interface, showed a trend toward the interface that was not significant for the whole sample. However, this trend was stronger and statistically significant for the multiple maker interface. Our quantitative results are also supported by the observation and interview data, showing that this interface is more preferred by the students. The quantitative results of this study are also consistent with another study, where multiple markers have been found in comparisons between different interfaces [22].

10.2 Effectiveness

Regarding effectiveness, student‟s self-reports indicate that the multiple markers application is more effective. This evidence was equally strong and it is consistent in all measurements that took place during the interaction process. Particularly notable is the multiple markers application whereby students mentioned that they could concentrate more on the contents and it was similar to a cell phone - touch screen interaction concept. Among other observations were that students could easily manipulate the 4BL mechanisms and see the simulations and working solutions instantly.

10.3 Easeness-to-use

Regarding easiness-to-use, the results interestingly indicate that in general the multiple markers user interface is evaluated as easier than the single marker user interface.

11. Conclusion

This study explored student‟s opinions and preferences regarding two augmented reality based applications for 4BL problem based on single marker and multiple marker interfaces. Both applications were designed to solve the same problem and used by the students to visualize the 4BL problem and have shown to be effective. The results indicated that the multiple marker based interface was more preffered especially for solving the problem, more effective and easier to be used as the students could concentrate more on the contents. Factors that seem to have influenced student‟s preferences include the prior familiarity with the cell phone touch screen concepts, it is possible to perform the simulation of a virtual object and generate the results in the real environment and integrate the virtual objects with the real ones, students could interact with the application more naturally and they were able to understand the problem better. The overall results could be concluded that most of the students agreed with the usefulness, effectiveness and ease-of-use of the multiple makers AR application user interface.

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