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Augmented Reality in Engineering Education: A Review

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Abstract : The review presented application of Augmented Reality(AR) in engineering education. The representative 29 papers reviewed from Google Scholar, IEEE Xplore, Scopus, and Web of Science. The introduction section explains the term AR, followed by the limitations of traditional teaching methods and how AR can address those difficulties. The review section includes AR app development phases, tools and technology used, AR apps for engineering education and feedback on students acceptance of the technology, improvement in academic performance.

IndexTerms **- Augmented Reality, Engineering Education, Learning performance.**

I. INTRODUCTION

The term "Augmented Reality" was coined by Tom Caudell and David Mizzel in 1990 first time **[1,2]**. AR is to bring in virtual 3D object in real world to better visualize and understand engineering concepts. It is merging of physical reality with digital or simulated reality. AR is an interactive, immersive technology which keeps its students involved into it completely and improves learning performance[5,11, 22]. The devices like Smartphone, head mounted device, Google lens can be used for visualization of AR applications.

Various streams in Engineering education like Mechanical, Civil, Electrical etc. includes many complex concepts [3-4]. The traditional teaching-learning methods makes it difficult to understand those concepts clearly. The practical experiments is an essential component of engineering education. But the laboratory set up includes heavy machinery and costly equipments which cannot be made available on individual basis for students. Few equipments are dangerous, hazardous may lead to accidents and need very careful and safety handling practices. The experimental labs generally made available to students for limited period. Such lab require large space for its set up and periodic maintenance is needed to maintain the lab equipments. Most of the times such labs are not developed or not maintained and remain idle. Sometimes the raw material cost to execute practical in such labs is also costlier.

Augmented Reality (AR) helps to deal with those difficulties in engineering education[12-17]. Virtual lab set up is an alternative to physical labs. It is affordable, user-friendly, available to individual student all the time, non-hazardous, maintenance free solution[8-9]. AR is becoming a major part of the prototyping process[18-21]. The review is an attempt to highlight application of AR technology in engineering education.

II. REVIEW OF LITERATURE

Engineering drawing is a universal language of an Engineer in which the students are asked to imagine a 3D situation and make the 2D orthographic projection drawing. As given by **Murthy et. al. [3]**, this part of 3D imagination and converting it into orthographic projection is difficult for students to mentally visualize. The AR tool developed jointly by BMSCE and Bosch (RBEI), Bangalore is proven to be an affordable, effective and immersive way to teach engineering drawing.

Shrestha [4], analyzed the effectiveness and usefulness of Augmented Reality (AR) in engineering education using an AR-based mobile app. To build this app Unity, Vuforia, C# were used. The framework to develop AR app and implementation in an engineering course is presented in this paper. The app assessment through a survey included a total of 48 evaluators. They provided feedback about the app and agreed that AR is beneficial in learning complex engineering topics. The researcher has claimed that traditional education needs to be supplemented with innovative AR-based tools to enhance engineering learning.

In engineering education, AR and Virtual Reality (AR/VR) technologies have been recently adopted in the teaching of technical subjects. It shows good potential for visual interaction with the objects which was discussed by **Arslan et. al.[5]**. In this study, experimental design with pre-test and post-test control groups and interviews were used to measure participants' success. The increase in performance between pre-test and post-test was 39.7% for the experimental group and 17.2% for the control group. The results indicated a 19.6% higher learning performance in the experimental group through the use of the AR application for training. This result shows that the mobile AR engineering drawing application had a very important effect in terms of acquiring new knowledge and skills from the participants.

Ivanov *et al.*[8], developed a mobile application based on AR which allows representing 2D drawings in 3D models. The main advantages of AR technology are simplicity, interactivity, and high performance in contrast to the use of traditional teaching

materials. **Attri and Lamba [6]**, **Kamińska *et al.*[9]**, also mentioned that Teaching and learning through virtual reality involve immersion, interaction, and involvement. This results in stronger retention of the presented material and improvement in educational outcomes.

According to **Dorrington *et al.*[7]**, use of VR to teach Mechanical Engineering Design enhanced opportunities for creative thinking, innovation, and problem-solving. The researcher explored the challenges of introducing creativity into an engineering course. VR was found as an effective methodology for the visualization of design concepts in the engineering design module.

Kamińska *et al.*[9] reported that VR/AR in education reduced the cost of putting a student in a high-risk, high cost, and difficult-to-access environment. Training is possible without the necessity of purchasing expensive machinery. In this study, an interactive virtual reality environment was developed to demonstrate that VR may serve as a relevant asset to the mechanical, electrical, and mechatronics laboratory.

Kaur *et al.*[10], designed and developed an AR(AR) based application-GeoSolvAR, that targets middle school students for improving their visualization skills. Learning activities in GeoSolvAR build on theoretical foundations of the Predict-Observe-Explain (POE) strategy to teach the concepts of 3D views like top view, side view, and front view.

The main stages of the development of an AR application are shown by **Kanivets *et al.*[11].** Particular attention is paid to the use of scripts to rotate and move virtual models. The in-house development of the AR mobile application for accomplishing tasks on a projection drawing is presented. The created mobile application recognizes marker drawings and displays the virtual model of the product on the screen of the mobile device.

Research by **Scaravetti et al.[12]** resulted in the contribution of AR in engineering education to improve the transmission of knowledge. It is a promising support tool to guide engineering students. However, it does not replace conventional tools.

Ivanova et al.[13], elaborated advantages of 3D virtual learning and measuring environments for Mechanical Engineering education. 3D virtual measuring simulations of Gear Hob tools are tested with engineering students of the University of Ruse. The learning performance and experience of students in the 3D virtual simulation environment compared with the real laboratory. Students found the virtual environment useful, fun, and attractive. They showed better results in their final reports.

Aliev et al.[14], presented a report that contains a description of AR technology application in the education and training of mechanical engineers. Software for AR marker tracking for Mechanical Engineering education was created and described. An approach for designing a textbook with 3D models of cutting tools, measuring tools, and special equipment, visualized using AR was presented.

Singh[15], overviewed AR in Mechanical Engineering and related fields. Also, the applications of AR in education, machinery systems design, maintenance, and repair and diagnostics, fault detection, inspection, and testing were reviewed. Technical challenges faced by AR regarding stereo view, color depth, luminance, high resolution, contrast, focus depth, and field of view were also discussed.

Booth [16], presented research into the integration and application of AR/VR systems in the fields of engineering education. The researcher discussed the potential benefits of AR/VR in engineering education by improving spatial skills for engineering design.

The research by **Poh et. al.[17]**, facilitated the use of AR to improve the efficiency of a design process, specifically in mechanical design. AR tool was designed for overlaying virtual objects in a real scene. During the development process, the limitations of ARToolkit in terms of accuracy and stability were observed.

The case study by **Lara-Prieto et. al. [18]**, suggested the use of AR and multimedia applications to generate tutorials for self-learning of the whole process of 3D printing.

Nee et. al. [19], presented that many researchers in the manufacturing industries, academic institutes, and universities have started exploring the use of AR technology in addressing some complex problems in manufacturing. Effective simulation before an actual operation ensures that it can be carried out right the first time, eliminating many trials and re-works, saving materials, energy, and labor. AR is becoming a major part of the prototyping process in product design in many industries.

In the research paper by **Kamath and Kamat [20]**, emphasis is given to the development of a cost-effective software suite for rapid simulation of the performance of mechanical systems in a virtual prototyping environment. The paper compares the developed software suite with the existing systems embodying active stereoscopic techniques.

S.C-Y. Lu et. al. [21] introduced, reviewed, and examined a new type of CAE tools, called virtual and AR technologies, to reveal its great potential in product realization. Specific areas where these emerging technologies can make a big difference are highlighted. Product development engineers and AR/VR researchers jointly deliver new products with high efficiency.

Takrouri et. al. [23] reviewed the opportunity to introduce both marker based and marker less AR in engineering education. The paper has given SWOT analysis around application of AR in engineering education.

Alejandro et. al.[24] presented exhaustive review of application of AR in engineering education**.** The authors pointed out that AR is not being used to its fullest potential, as available the AR apps are not full-fledged. The researchers, developers need to put in efforts to develop AR applications for engineering education.

Bacca, J. et. al.[25] mentioned that AR has been mostly applied in higher education and has potential in children education and vocational training. The authors found that Marker-based type of AR is widely used. AR applications resulted in interactive, immersive learning that has improved students performance.

Murat Akçay et. al.[26] explained the potential of AR in teaching learning process. The advantages of AR in educational setup like enhanced learning achievement, increased interest, interaction opportunities, reduction in laboratory material cost ets. are enlisted and explained. The limitations like difficulty in use of AR app, inability to use the technology, technical problems etc. are also mentioned.

Heen Chen et. al.[27] proposed marker-based AR application for learning Engineering Graphics. It has used book as an interface to superimpose 3D virtual model which helps to understand the relationship between the 3D geometry and their 2D projection.

A. Sánchez et. al.[28] evaluated the usability of AR technology on mobile devices by performing an experiment in three stages as PRE-Test, lectures, and POST-Test. The experiment carried out on 3 control groups and 1 experimental group of students and the findings concluded that experimental group involved in AR-specific training improved academic performance and found more motivated learning.

Shirazi, Arezoo et. al.[29] found that context aware mobile augmented reality tool (CAM-ART) is an interesting, helpful, and motivational approach in the classroom that helped them gain more in-depth and long-lasting knowledge beyond what is normally expected from traditional lecture-based teaching methods.

III. Conclusions

The review explains various types of AR app developments like marker-based, marker-less etc.. It is found that marker based AR development is very common and accepted in education domain. The devices for AR apps include smart phones, tablets, laptops, desktops etc. It is observed that most of the AR apps are developed for smart phones due to its user friendly, affordable acceptance. It is reviewed that use of AR apps in engineering education has enhanced learning motivation and academic performance of students.

IV. Future Scope

AR can be added into engineering curriculum and AR Book can be developed for subjects like engineering drawing.

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