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Case based Study: Computer Visualization of Engineering Problems and its Impact on Student Learning

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Abstract - To investigate the effects of computer-based visualization techniques on engineering students' diagnostic competence in the context of a web-based learning environment containing case-based worked examples, two main studies were conducted. In the first experimental study, the learning results were measured by a formative assessment such as in-class activities, quizzes, case studies, etc. Data was collected and measured using a questionnaire that was randomly distributed to the electrical engineering students. It was found that the acquisition of knowledge can be supported by eliciting the use of 2D, 3D images, drawings or illustrations, etc. It was also noted that learners with low levels of prior topic knowledge profited from the computer-based visualization techniques. In the second study, results were analysed from the summative assessments such as final exams, final practical tasks, and final projects where positive impacts were observed on students' learning. Overall, the findings underline the "direct" relevance of the quality of knowledge attainment by learning from computer-based visualization techniques.

Keywords: Visualization techniques, Student Learning, Web-based Learning, Formative Assessments, Summative Assessments

INTRODUCTION

Computer-based visualization techniques, like creating images, diagrams and animations are an effective way of communicating messages. These interactive multimedia techniques can give a wonderful communication of engineering concepts, especially of electromagnetic fields. Most of the engineering materials are paper-based and educators are continuously trying to integrate modern multimedia techniques into the curriculum. Today computer visualization has ever-expanding applications in science, education, and engineering. Next to, it is the interactive visualization, which is the graphical illustration of live process information that can help in understanding the processes more efficiently as we can analyse human input and response time in virtual reality.

Engineering educators usually face a challenge in higher education in building and implementing technology-rich curriculum and effective learning environment. In addition, different students have different learning styles that need to be taken care of. Techniques like handouts, PowerPoint presentations, problem-based learning, and hands-on practice in the lab are being used in understanding the concepts of theories of engineering. Conventional lectures using board markers have however, limited scope to convey complex electrical concepts and processes. Images drawn on

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whiteboards or on books are not sufficient to demonstrate the processes in detail. Complex events can be modelled to visualize the engineering phenomena that cannot be observed directly (Akram et al., 2021). Computer graphic techniques, images, animations, and different software/simulations allow students to develop a better understanding of complex theories and concepts. This technique of using computer-based presentations can help in better delivery of complex theories and processes of electrical engineering (Hassan et al., 2017). Most of the students find computer-based presentations less stressful tasks and this supports their deep learning skills.

Higher Education Institutions (HEIs) are investing tremendously towards the implementation of eLearning in the curriculum and state-of-the-art hardware and software resources are being deployed. The intranet, internet, web 2.0 tools, and Moodle are available, however there is a need to make better use of these resources towards a better student learning experience. Since learners have very high expectations of their tutors regarding the use of technology that should be appropriate to the subject matter. To meet these expectations faculty members need to polish their technical skills so that they could mentor students even better.

SYSTEM MODELNTRODUCTION

The main intention of this research work was to incorporate the computer visualization techniques in engineering lectures and to observe the impact on student learning and satisfaction. In this practice, different images, animations, and video clips were searched and demonstrated to students during in class activities. The engineering students were exposed to different visualizations of engineering concepts incorporated in lectures (Akram et al., 2019). Few of these visualizations were taken from open online sources, while others were designed for the lectures. During practicing this technique, in general, the lecture included a statement of the problem, a description of the rules/laws and principles available to solve the problem followed by examples/case-studies to elaborate the physical meaning of the laws and concepts. Normally more than one examples were solved to give understanding of various aspects of the concepts (Voltmer and Garner, 1998; Khattak, 2020). Then students had to think and solve related engineering applications. Simulating software and programming languages were presented to students that can generate 2D and 3D electrostatic, magneto-static, and electrodynamics wave models and can solve them as well. The technique allowed students to concentrate on the physical meaning of the abstract concepts, hence to get an in-depth understanding of the theory. Along with assessments, formal feedback was conducted to measure students learning.

In this practice, we can say that the learning process is divided into three stages as learn, practice, and assess. Initially, students went through dialogue and visualizations to understand the concept. Dialogue includes prior knowledge discussion, identifying problems, discussion of available theories which explain the process, and question-answer sessions. Visualization was used as video clips, drawings, 2D and 3D models, pictures, and animations to have a better understanding of concepts. Secondly, students applied their acquired knowledge to work on practical problems/case studies. Finally, learning was assessed by feedback process using formative and summative assessments. Student score measured their learning which was also mapped to the module outcomes. The methodology is illustrated in *figure 1*.

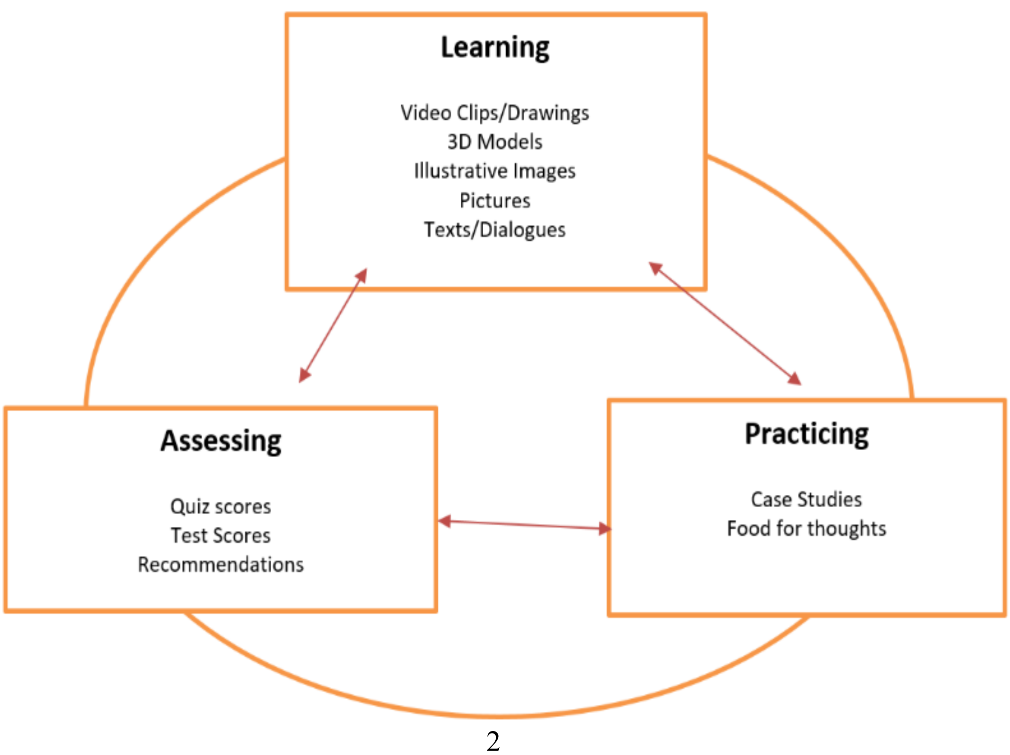

Figure 1: Methodology of the Research

Different computers based on animation software, multimedia technologies, and programming language as Visio, Flash, CAD and MATLAB helped in implementing this research work. Further utilization of the internet, email, word processing, VLEs, video conferences, use of presentational hardware and software, Web 2.0 tools, and mobile technology were used as activities for this practice (Ul Haq et al., 2020, 2021). Online resources from different e-Learning websites were searched and shared with students. Students were asked to look into the aspects of technology like, what activities can be prepared using particular technological tools.

Figure 2 presents two examples of the use of this technique in lectures. The first example is of the traveling wave in the waveguide. Usually, the subject of electromagnetic fields is considered one of the most difficult subjects in the undergraduate curriculum of electrical engineering. The reason being unlike other branches of engineering as mechanical, civil, or mining which deal with concrete objects, almost all subjects of electrical engineering and especially electromagnetic fields deal with invisible waves which are present in space around us. These invisible waves (electromagnetic fields) are however harsh in their formulation and require a sound knowledge of the concepts and principles. Especially those students who have less aptitude towards mathematical abstraction and are not able to make images of the phenomena in their mind may lose interest in it. Visual perception may enhance their ability to interpret information and may prove much more effective than oral communication of the concept (Miller, 1992; Nawaz 2020). This visionary concept was used in understanding the physics of electromagnetic fields and hence applications of electrical engineering (Rao, 1990) while practicing the case study. Figure 2 also shows animations of field distribution image, simulation results for the wave, wave pattern, and wave travel animations which were exposed to students.

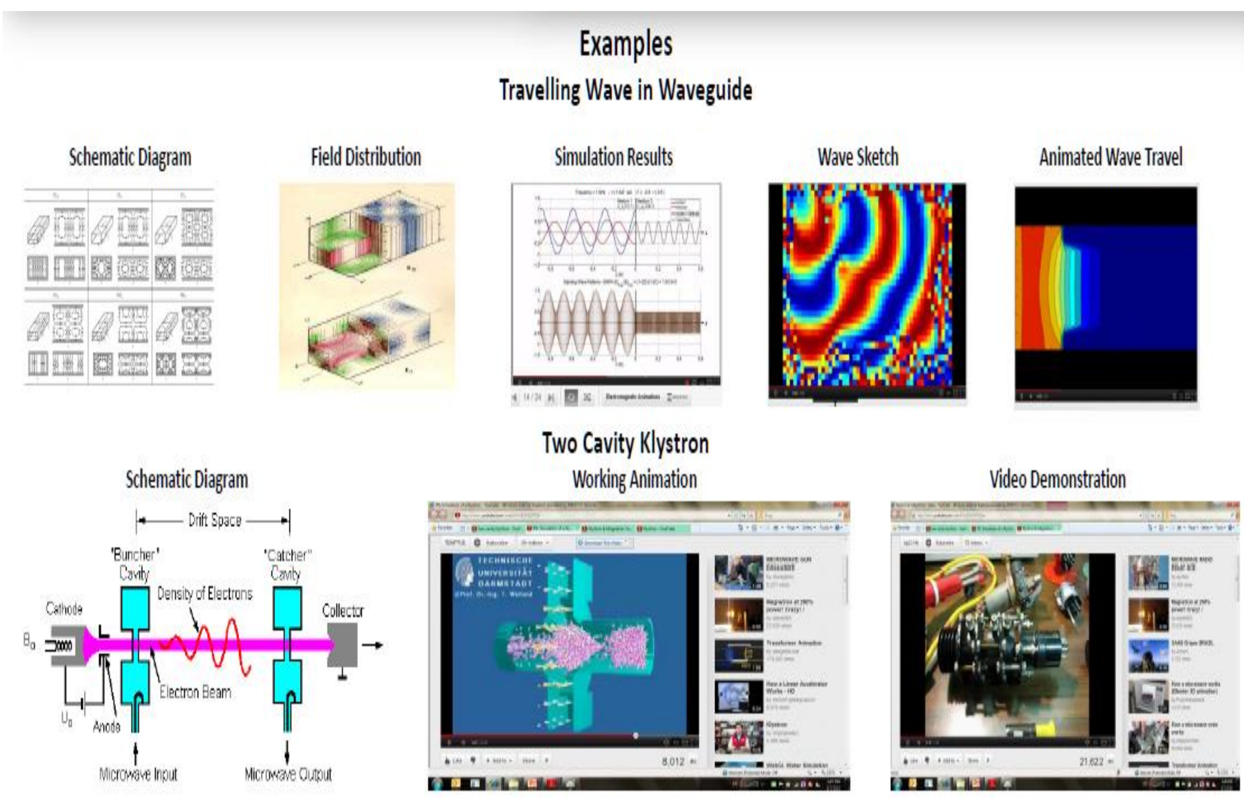

Figure 2: Examples of Computer Visualization

It was found that the response of the students was much better after this exposure during in-class discussions. Short quizzes and problem sheets were used to solve related case studies and students were assessed later on their understanding. It was observed that the involvement of students in lectures was much more as compared to previous sessions conducted without such activity and students got good results in quiz and problem-solving. Feedback mentioned that this enhanced their satisfaction level.

The second example demonstrates the working of a typical two-cavity klystron tube to produce EMF oscillations in the microwave range. Students easily understood the working process with the help of one animated presentation and video presentation.

RESULT DISCUSSION

This practice involved gathering information from different sources, analysing that information, delivery of concepts and theories, and developing a virtual learning environment, use of information and communication technologies (ICTs), e-practicing, and e-learning skills for the self and students. The practice was carried in electromagnetic fields and microwave communication systems module classes. The questionnaire designed to gather feedback included the following questions:

- Do you feel that visuals in the lecture clearly explained the concepts?
- Do you find animations and video tutorials used in lectures useful?
- Do you feel animations and video tutorials have enhanced your learning of the topics?
- Is the pace appropriate in which do you learn?
- Does the framework of the lecture using computer visualization help you in relating learning to the real-time world?
- Do you feel that this practice should be continued?

The majority of the students agreed that this technique helped them in better understanding of the topics and should be continued. Few comments are:

- *"That's probably what we want and should be adopted in all modules".*
- *"I think this will help us".*
- *"Good, I appreciate this kind of lecture".*
- *"Teacher did a good job".*
- *"Good explanation of the topic".*
- *"Video tutorial was lengthy".*

The outcomes from the feedback from different sessions are summarized below in *figure 3* as:

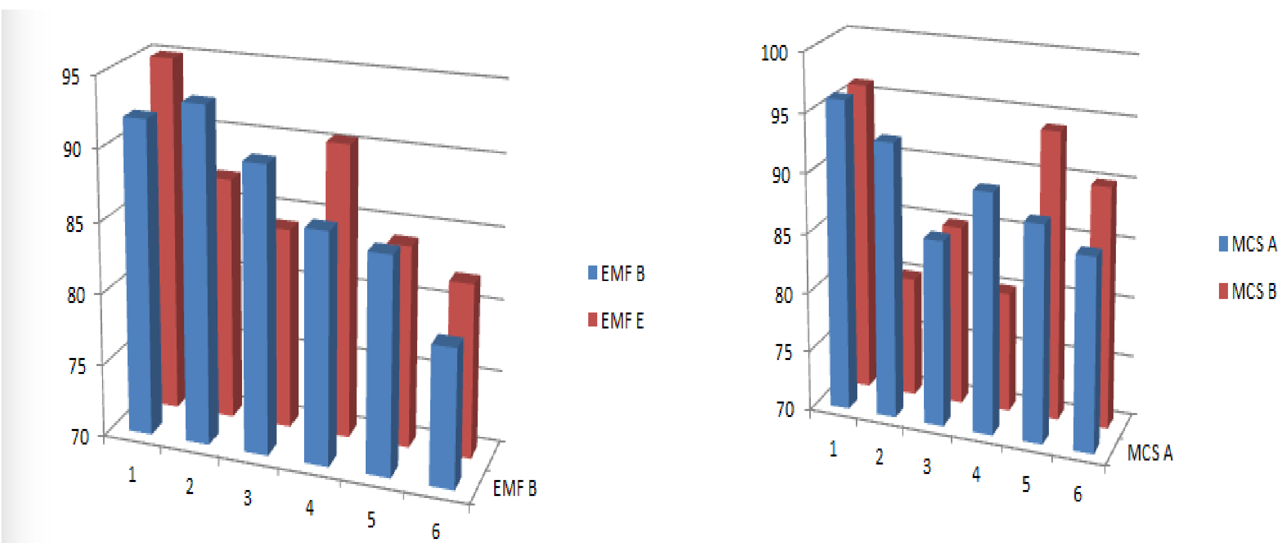

Figure 3: Analysis of Student feedback on Methodology

Overall positive feedback was received on the practice. A range of literature was reviewed to find the conceptual understanding of the practice as well. To search and develop for the images and simulations for the topics, we had to spend much time, but this helped a lot towards the satisfaction of our students. We found that if students are demonstrated only schematic diagrams of field patterns, some students who have got less aptitude towards abstract thinking can lose interest in the class. The feedback and assessment results indicate that the desired effect on the student's learning has been achieved enhancing students satisfaction. It was observed that during the use of this technology, students responded better. The reason for this is that, they are exposed to the latest technologies with applications in their subjects and by being versed in different computer applications to learn their subjects in a better way. Engineering Education Using Computer Visualization innovation (sometimes referred to as digital literacy) is aimed to use the application of technology towards enhanced learning. The computer simulation in a variety of electromagnetic problems is expected to help students in their in deep learning enabling them to get a better understanding of the nature of different phenomena, where students are exposed to a range of models using computer visualizations (Boulter & Gilbert, 2000; Gilbert & Boulter, 2000; Treagust, 1996; Akram et al., 2020; Abro et al., 2020).

CONCLUSIONS

The main expected outcome from the research work was the assessment of student learning finding a framework to build a deep learning approach in teaching, acquiring lifelong skills, in the sense if students are able to visualize a process, they can retain it for longer, acquisition of knowledge, increased motivation and ability to progress. Time constraints remained the major challenge in implementing virtual reality in lectures. Technical skills of teachers and students also play a vital role in making lectures more fruitful being interactive. Many platforms like H5P and Moodle and software are now available to design graphics, animations, and videos that can be used to develop the content. Along with skill set in displaying the interactive processes, the cost factor should also be considered. Faculty members should approach different subject centres of HEI to get specific support in making the practice implemented. Web resources and library resources need to be dugout. The resource equation may be used to identify in detail, the resource requirements to support this practice (Doug Collins, 2011). This research can be further developed with interactive techniques. Feedback about innovation demonstrates that it is good to use advanced visualization techniques to educate engineering students, providing them dynamic representations of knowledge.

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