Teacher Receptivity in Creative Use of Virtual Laboratories

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***Abstract*—: Technology has helped advance science education in its delivery of content to students. These advancements have led to improved conceptual understanding of physical phenomena in students. In most educational systems, teachers play a crucial role in the introduction of innovative pedagogic interventions. In this paper, the perceived impact on use of virtual laboratories and simulations as a teaching aide in science education by teachers is characterized. Significant improvements on teaching time, teaching methodology, and communication of concepts over traditional teaching techniques are reported. The value of virtual laboratories in individualized learning as opposed to group centric learning as in a conventional laboratory is further explored. Key challenges to complete adoption of these technologies include infrastructural lacunae and depth of teacher knowledge. Hence the individual teacher commitment along with the necessary ICT support can impact the knowledge environment. With functionality to simulate real environments, create assessments, monitor individual student performances, added to the scalability of the virtual laboratory platforms to encompass multiple thematic disciplines and cater to millions of users makes it a sustainable and a need-to-have teaching tool.**

***Keywords*— Virtual Labs; Conceptual Learning;Teacher creativity; Physics; Simulations;**

I. INTRODUCTION

The 21st century requires individuals and communities to develop better adaptability and exercise non-routine problem solving approaches to global challenges. With decline in participation in STEM education (Science, Technology, Engineering and Mathematics), there is a grave concern on the sustainability of existing resources and solutions along with poorer participation of the wider public in development of alternate strategies and mitigation of risks. Several studies [1,2,3] have indicated that unless proactive strategies to invoke curiosity and interest are undertaken towards learning science, tremendous talent would remain untapped.

The value of using multimedia based teaching tools and enhancing student interest and participation is well known [4,5]. In areas related to STEM, although initially, java applets, video tutorials and so on were used to assist with drill and practice learning modes, today, multimedia tools are used to offer complete courses and provide more investigative and exploratory learning experiences to students.

One of the areas important to STEM education is the practical experience students gain of physical phenomena from experimentation in laboratories. In most educational institutions due to high volume of students and lack of infrastructure and limited time, it is difficult to provide individualized training in laboratory practices. This leaves students with suboptimal knowledge of the governing concepts. This paper discusses the use of virtual laboratories to bridge this gap and providing teachers a substantially effective alternative to provide the required training in conceptualizing the underlying laws of experimental phenomena.

II. LITERATURE SURVEY

Faculty of higher educational institutes are not required to take additional training in teaching or pedagogic practices as in the case of K-12 teachers to teach undergraduate or graduate students. However, the expectations are that faculty will have to develop a variety of multi-tasking skills in dealing with the cognitive development of students from diverse backgrounds, attitudes and perception without specific training to do so. In spite of standardizing curricular content at national or international standards by many institutions, poor teaching practices debilitate students from competing globally. Needless to say, this variation in the quality of education ultimately affects workforce productivity.

Thus empowering teachers and faculty in higher educational institutes with techniques and tools to enhance content coverage, assessment and delivery while being aligned to changing social environments is of paramount value. There have been numerous studies that have showcased the need to use digital technology and Internet and Communication technologies (ICT). Inspite of the existence of powerful technologies [6,7], a several factors have contributed to the adoption of these technologies in traditional classrooms. Zhao et. al [8] analyze the barriers of technology innovations in the context of education. In their work, they emphasize that the involvement of teachers is of

978-1-4799-7606-5/14/$31.00 ©2014 IEEE

primary importance for any innovation to create a vast impact on students. More specifically three aspects namely technology proficiency, pedagogical compatibility and social awareness contributed to the impact of teachers. Technology proficiency meant familiarity with the technology and its enabling conditions. The pedagogical compatibility is the alignment of the technology intervention to their personal beliefs while social awareness is their ability to manipulate the social influences favorably. A study by Kriek et al [9] using a 'combined model' of technology acceptance model, innovation diffusion theory and theory of planned behavior indicated that the perceived usefulness and beliefs of teachers significantly impacted their use of simulations in physics teaching. However lack of prior training in ICT, absence of customizing education to individual students in a classroom setting and changing peripherals can be challenging to non-IT savvy teachers [10,11]. The lack of confidence stems from the dearth of exposure which in turn results in apprehension towards technology as described by B-Andoh et. al [12].

Teachers have sought information from books, journals, more recently the internet to assist with their teaching needs. A description of their teaching instances with factors influencing them and resources used have been captured in [13]. The results from this study [14] indicated that accessing quality technological resources positively affects pedagogic aspects of teaching. They also found that most teachers use technologies only to prepare lesson notes or assessments and have not explored their utilization with respect to student performances. Confirmation that an increase in motivation and willingness of teachers is possible if they are exposed to ICT has been shown in a few studies [15,16]. Considering the significant role of teachers and the importance of science education, engaging and immersive technologies would go a long way in assisting the teachers impart an understanding of science to a generation of students that resonate to an ethos of web 2.0 technologies. Ertmer et al. discuss the different order of barriers in technology adoption by teachers and indicate how the barriers of technology integration from teacher attitudes, beliefs and knowledge are far greater challenge than resources, training or support [17]

This paper focuses on the receptivity of teachers after exposure to virtual laboratories (VL). The VL platform studied in this paper is one of the largest set of online laboratories [18] built for the teaching and learning communities in India. Targeted to reach out to more than 500,000 students and over 600 universities, the platform contains over 1500 virtual experiments as part of ~ 200 online labs. With coverage of nine thematic areas in the engineering and sciences, the pedagogic components integrated on the platform are unique. With over 800 participants from 12 universities in India, the VL project has contributed to STEM learning in a significant way.

III. REASEACH METHODOLOGY

The study was carried out in central India in the state of Madhya Pradesh. The literacy rate in Madhya Pradesh is approximately 70%, which is lower than the national average of literacy in India. The teachers that participated in this study hailed from polytechnic colleges located in semi urban areas. Polytechnic colleges in India offer diploma courses to those students that do not qualify to top higher education institutes that specialize in the sciences and engineering. Most students attending polytechnic colleges hail from rural areas, whose medium of instruction may not be English. One of the challenges with polytechnic institutes is that the diploma courses have been diluted in quality over the years resulting in disappearance of skills components from their curricula [19]. This alarming state of affairs led to the introduction of ICT technologies to the faculty so as to enhance the skills development. More importantly, presenting the content in the most effective way is important. An ability to provide visually appealing simulations, the theory, the procedure, assessment questions etc. contribute equally to the success of the delivery of the content.

A. Virtual Laboratories Workshop

The program consisted of providing a focused workshop on VL to faculty from over 20 polytechnic institutes. The workshop was carefully planned to allow teachers to immerse themselves in learning about VL for its use as a teaching aide. The workshop consisted of three initial parts (Fig.1) namely an introductory session, followed by a demonstration of the VL experiments, after which there was a hands-on training session was provided.

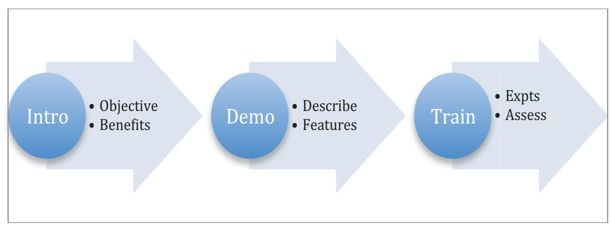

Fig1. Workshop Design

In the introductory part, the goals and objectives of the VL project were presented. Information on how VL was developed, the partners and the themes were broadly described. The oral presentation was interspersed with video segments drawing the attention to the key aspects of the VL project. In the demonstration session, the pedagogic aspects of VL that included going over the theory, procedure, self-evaluation quizzes, simulator, the assignment and the reference tabs were elaborated and shown in detail. In the third session, hands-on training was given to vary the experimental functionalities and observe the resulting data. In addition, teachers were given training on use of assessment platform to monitor the performance of their students.

B. *Virtual Experiments*

This study focused on two physics experiments selected from the optics VL labs. The first one was related to virtualizing the Newton's rings to determine wavelength of light. When light is passed through a film, it transmits and reflects light. The experiment involves allowing light to pass through a glass plate of known thickness and inclination of 45° and capturing the reflected light through a convex lens that is kept in contact with glass plate. When this viewed through a long focus microscope, fringes from interference of light are observed. By measuring the distance of these fringes, the wavelength of the incident is calculated. The radius of the lens can be varied up to 100cm and change the size of the fringes. The position of the microscope can changed to allow easy measurement of them. A magnified view of the graduated scale assists with accurate measurements. The advantage of doing this experiment using VL is that several factors that are difficult to modify in real environments can be easily studied such as 1) switching the light source between sodium, neon, green or red light and 2) medium between the glass plate and lens such as air, water, acetone, isopropyl alcohol or kerosene.

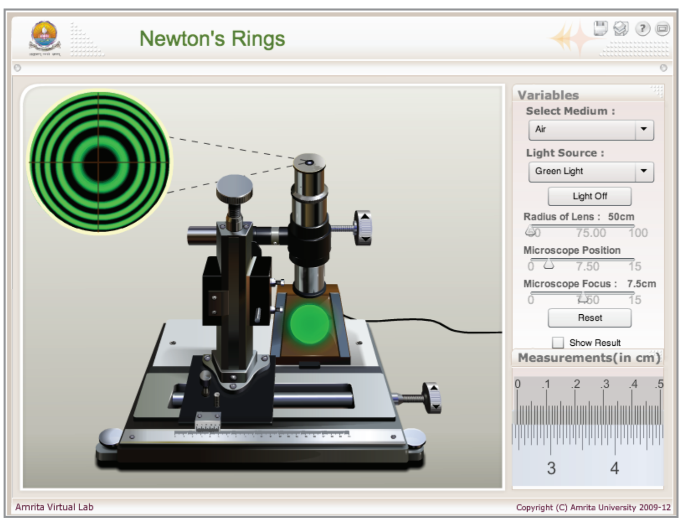

Fig. 2 Newton's Ring Apparatus

The second experiment was use of spectrometer to calculate the refractive index of a prism (Fig.3). As a first step, the spectrometer telescope is tuned for good focus. Then turning the on light and placing the prism, the refracted light from the prism is traced. The learning outcomes and difficulties in conducting this experiment in physical lab is explained here [20].

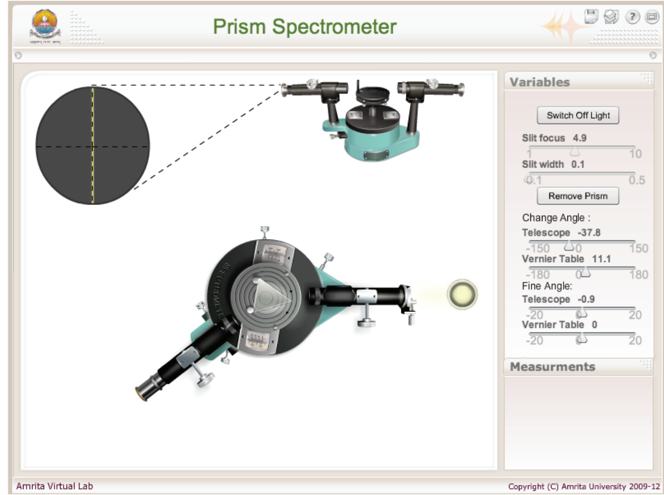

Fig.3 Prism Spectrometer Experiment

C. *Teacher Feedback*

The VL experiments provide interactivity while imparting procedural knowledge. Having gone through the experiments in detail, the teachers were requested how they would integrate VL into their teaching and learning practices. Feedback was requested in the form survey that combined multiple-choice questions and invited descriptive comments based on criteria proposed for software [21,22]. There was also an informal interactive session with teachers that allowed them to express their suggestions, questions or requirements. Key factors that will influence the usage of VL such as availability of internet, computers etc. related to the infrastructure were also obtained.

IV. RESULTS ANALYSIS

The theoretical framework of Technology Acceptance Model (TAM) describes two fundamental factors [21,22] affecting adoption of any technology i.e. the perceived usefulness (PU) and perceived ease of use (PEOU). The former represents the extent of usefulness as perceived by adopters while the latter represents how easy the technology is to use. The purpose of this study was to examine TAM of VL and receive feedback based on the basic criteria of perceived usefulness Three aspects of teacher receptivity that are expected to contribute to the usage of VL technology were the primary focus of this study. They were: 1) the time taken by the teacher to explain and elaborate on a concept 2) teacher's perception of what percentage of students will benefit and 3) teacher's perception of the ease and effectiveness. A comparison between traditional classroom teaching versus VL was done. The teachers that were part of this study had educational backgrounds that included either an undergraduate degree (47%) or a graduate degree (53%). Their teaching experience averaged approximately 12 years. The graduate degree included those with PhD as well. The average number of students they teach every year was between 60 and 100 students (Fig. 4).

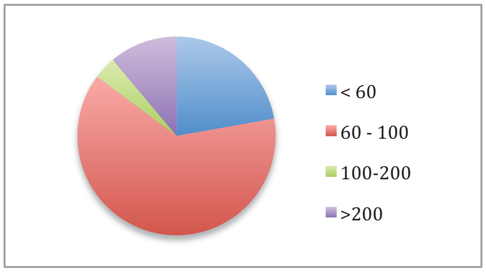

Fig. 4 Average No. of Students Taught Per Year by Individual Faculty

One of the most important aspects of using VL is the presence of the required infrastructure. In these institutes that were trained to use, an average number of computers that a teacher could avail in their respective department was less than 30 (Fig. 5). Twenty percent of the institutes had less than 10 computers with two of them mentioning frequent power fluctuations. It was also verified that most institutes had 2Mbps connectivity at their respective locations.

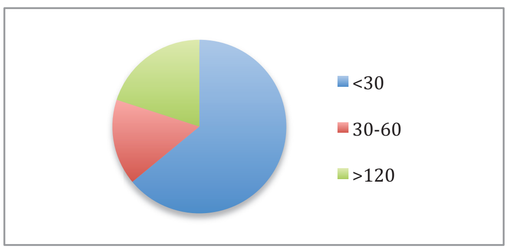

Fig. 5. Average No. of Computers Available for VL Per Institute

The effective receptivity of teachers were analyzed by descriptive statistics that included the mean and standard deviations. The first experiment relates to the spectrometer. Most of the teachers agreed in the case of using a textbook, the time taken to explain the concept of angle of minimum deviation would take on average approximately 30 minutes (M=2.0). The same set of teachers felt that explaining the identical concept using VL would take less than 10 minutes (M=1.38). This is depicted in Fig. 6

The teachers were then asked about how much time it would take them to explain the differences between the angle of incidence and the angle of deviation and most felt that would take an average of 25 minutes (M=2.44), while the same differences could be elaborated with visualization effectively with a little more than 10 minutes (M=1.62). So teacher's perception is that there is substantial time savings in "explaining a concept" using VL simulator in the classroom. Hence the teachers will be positively disposed towards using the simulator in the classroom. Their attitudes and beliefs are what will make them adopt the simulator to teacher.

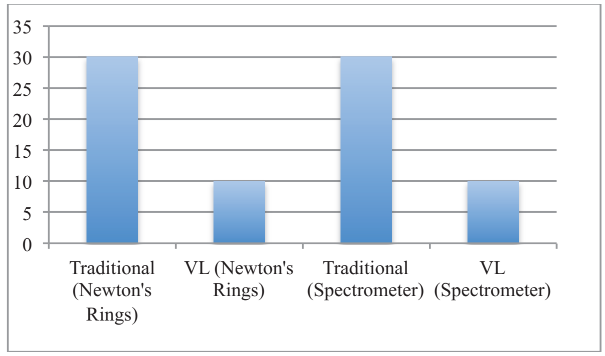

Fig. 6. Comparing time taken to explain concepts

The next set of questions dealt with the understanding capacity of their body of students. Teachers felt that less than 60% (M=2.85) of the students understand the concept from classroom teaching, while they feel over 80% of students (M=4.1) will most definitely understand these concepts if taught using VL. This suggests a strong motivation to adopt simulator in the classroom to teacher.

A critical insight drawn based on the above results is that teachers perceive that they will actually take less time to teach a concept using simulator and substantially higher number of students will be benefit from this approach. This was further substantiated by the fact that an overwhelming 100% of the teachers felt that the simulator would explain the concept far more easily. This is because in order to teach the significance of angle of minimum deviation, the teacher has to draw a lot of diagrams with different angle of incidence, which is a time consuming process and could be done by an instructor with fair drawing skills. This simulator helps the teacher to explain this idea within ten minutes and the students can visualize the concept.

In the case of using Newton's ring experiment, when asked about how long it would take to explain the theory of Newton's ring experiment, the response indicated about 30 minutes (M=2.06). With the help of the simulator on the other hand, most teachers felt it take less than 10 minutes (M=1.23). Interesting to observe that 76% of the respondents are using the traditional blackboard to teach with another 22% using power point. Practically no one is using any virtual learning approaches to teach the concepts though they agree that theoretical derivations of intensity and diameter of the ring concepts are a lengthy and time consuming.

Teachers overwhelmingly agreed that concepts like variation in fringe diameter with the focal length of lens and how the liquid in between glass and lens influences the ring diameter can be easily demonstrated with the help of simulator. When asked if the "the simulator of Newton's ring will help teacher in teaching the concept", almost 89% of the teachers agreed that it will help dramatically reduce the time to explain the concept and that the students will understand the concept easily and faster with the visuals.

V. Conclusions and Future Work

Teachers have been primary drivers of quality education. They have shaped the edifice of STEM related human resources by paving for promotion and adoption of scientific careers amongst young students. In semi-urban areas, the access and quality of knowledge imparted may be impacted by a number of factors. It becomes imperative to equip teachers with necessary tools to assist in their educational endeavors. Application of TAM to usage of VL has been validated as part of this research. This study highlighted the how VL can radically change the mode of delivery of technical information to undergraduate students assisting with visualization, and engagement to improve learning. More than 60% improvement in the time to teach concepts was reported by teachers who had an average of 12 years of experience. Teachers predominantly felt that teaching concepts using VL would shorten the time to teach that specific concept by over 65%. A large swing in the extent of student learning perceived from VL was also reported. From less than 60% of students understanding concepts as taught in traditional classroom, teachers felt VL would help more than 80% understand them better. Having an ability to offer the content in an offline mode would have catered to the those institutions that have power or poor internet connectivity. Future research should compare the influences of each of the components of VL to content delivery, and its perceived usefulness. As mentioned in [16] the second order barriers such as teacher beliefs and attitudes can be positively affected for technology adoption using VL. Thus VL paves way to student centric learning and addresses the lack of content architecture and teacher knowledge effectively. The scalability of the system to accommodate multiple users and its architecture allowing multi-lingual conversions to serve large and diverse students should be further characterized in terms of perceived ease of use.

Acknowledgment

Our work derives direction and ideas from the Chancellor of Amrita University, Sri Mata Amritanandamayi Devi. The authors would like to acknowledge the contributions of faculty and staff at Amrita University whose feedback and guidance was invaluable.

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