INTEGRATING TECHNOLOGY WITH SCIENCE IN STEM EDUCATION FOR K-12 STUDENTS

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ABSTRACT: Science Technology Engineering and Mathematics (STEM) Education is vital for the economy and future employment in developing countries. However, STEM education in Pakistan is still an emerging topic, especially in Hyderabad. Numerous challenges have been found in introducing STEM education as it is complex, unavailable, lack of usability in the education curriculum. STEM education is found to be a suitable learning technique for both teachers and students of Kinndergarten-12 (K-12) grade. This paper introduces an integrated technology and science-based web application that provides an animation-based learning and teaching application prototype. A preliminary survey was conducted from teachers to assess their Information Technology (IT) knowledge and its use in learning and teaching. There were 60% teachers used projectors in the lectures, while the 33.3% used class board and markers, and the remaining 6.7% used only hand gestures to teach their students. Later, the prototype was experienced to see the feasibility and understanding of teachers. 46.7% of teachers voted for the prototype interface as interesting to use while the remaining percentage voted as an average and confusing interface. It was noted that teachers with less education levels had less interest to use this prototype application, however, teachers who were familiar with basic IT skills were likely to use this application. In the end, the last question about using the prototype application in their lectures showed that 80% of teachers will use this application in every practical lecture while 20% of teachers would use this application whenever they get time to prepare for it.

KEY WORDS: *Learning, Information Technology, educational system*

1. INTRODUCTION

In developing countries, educating youth directly improves the economy and prosperity of the country. Moreover, educational systems prepare the youth for dynamic, challenging, and vibrant, workplaces with sophisticated technologies. Over many years, Science Technology Engineering and Mathematics (STEM) has been emphasized as a competitive edge of the global shift in educational systems. Although STEM education itself is a very broad topic including all the disciplines such as science, mathematics, technology, engineering, and combinations of cross-disciplinary STEM itself (Wang et al., 2022). It is to be noted that the idea of STEM education in Pakistan is still emerging, in comparison to other countries where it has already prevailed (Hali et al., 2021). The disciplines of STEM education in

Pakistan are viewed to be difficult and challenging based on their complexity, unavailability, lack of usability, and multi-dimensional nature of its practicality. The National Science Foundation has emphasized that game-based STEM learning in K-12 education is a suitable tool for both students and teachers (*Science, Technology, Engineering and Math Are Highlighted at Community College Day 2008 | NSF - National Science Foundation*, n.d.). As a result, STEM education creates such students that remain critically able to determine the solutions to ills in modern society. On the other hand, the normalization of STEM in Pakistan is a deprived topic. The major reason for this is the absence of government policies resulting in low educational infrastructure (Hali et al., 2021). The government of Pakistan came upon a solution to realize the significance of STEM education and engaging it with Higher Education Commission (HEC) and universities to bring about an innovative and technological curriculum (The News, 2019).

On the other hand, the approaches of traditional teaching and learning which involve lecture handouts, note-taking, and rote memorization results that students in such an environment do not acquire different skills of learning and answering the questions analytically. There are innumerable pieces of research on education emphasizing the significance of pedagogical learning with a blend of technology-based learning and teaching (Hajirasouli & Banihashemi, 2022). In the 21st century technological revolutions, various technological achievements, especially smart devices such as mobile phones, laptops, and tablets have transformed routine life into digitally enhanced virtual environments (Amanatidis, 2022). The utilization of these technological environments and teaching science subjects to k-12 students with the integration of technology-based learning within these smart devices will reveal an upgrading shift in education curriculum. However, technological-based STEM education has not yet been researched widely (Sáez-López et al., 2019). In addition to it, for learning, students and teachers find YouTube service and mobile applications, augmented and virtual reality applications freely available on the internet (Osadchyi et al., 2021). These services make lessons more interesting, especially in science subjects, in those education environments of Pakistan where traditional methods of teaching and learning are being followed for decades. In reputed education environments especially above K-12, educational and practical materials related to technology are either limited or are not being used due to a lack of preparation by teachers. However, in K-12 education institutes, such methods of integrating science with technology as part of STEM education are not even discussed in governmental policies or are very less implemented in well-reputed institutes. Though, there are few software and technical resources available for the deployment and integration of science with technology-based STEM education, but to the best of our knowledge, there is no application in use in the local context. Therefore, the objectives of the current study are as follow:

1. To identify the gaps in STEM education by teachers of K-12 grade
2. To develop an animation-based video prototype for STEM education
3. To evaluate the prototype in the local private schools.

A. Problem Statement

To implement the solution to this problem, a prototype is created in such a way that an animated graphical learning application is developed which will be used by teachers to create interesting video lectures such as designing a video-based

explanation for understanding covalent and ionic bonds in chemistry, laws of inertia in physics, and so on. The teachers are given pedagogical learning techniques with a mixture of how to use such applications based on their science subjects.

2. LITERATURE REVIEW

The research related to STEM education was previously conducted in Gulf Cooperation Council (GCC) countries to identify and fill the gap of STEM learning. The targeted audience was K-12, undergraduates, graduates, teachers, parents, and faculty members. The study found out that the audience's demographic and cultural factors were responsible for not promoting STEM education in GCC countries (Kayan-Fadlelmula et al., 2022). Another paper was studied which focused on game-based learning for STEM education of K-12 students. The results denoted that students were more driven to digital-game-based methods which also improved their academic performance (Wang et al., 2022). There was another research conducted on STEM education trends in Pakistan for the purpose of improvising the trends and promoting their quality in Pakistan. Though the paper identified an alarming lack of research on the availability of STEM education in Pakistan. But, the available literature found that most of the science and technology subjects were based on digital learning (Hali et al., 2021). Another paper based on STEM education in Pakistan highlighted the lack of technical equipment available in educational systems which directly impacts the demotivation of students (Hali et al., 2021). One more study conducted in the KPK province of Pakistan for STEM education and it found the gap in the lack of technology and academic resources for students (Iqbal et al., 2021). A new study was conducted for the purpose of Lesson Study Model (LSM) into distance study for STEM education in the covid19 pandemic. The results indicated a positive impact on the study of students than the environmental and technical challenges faced by both the teachers and students (Aykan & Yıldırım, 2022). One more paper was studied which identified the gap in promoting STEM education. The paper was formulated as a systematic review and a issue was identified in the performance of teacher who was responsible in outdated teaching methods (Yuzie et al., 2021). One more research conducted in America for the different demographic groups impact on STEM education. The study proposed to eliminated cultural constraints when promoting STEM education in American educational institutions (Bhatti, 2021). One more paper highlighted the awareness of STEM education in secondary schools of Pakistan. A questionnaire was distributed in 350 secondary school teachers and statistical tests were conducted on selected data. The results indicated that teachers were aware of the knowledge of STEM education and were enthusiastic and dedicated in promoting the learning methods of STEM education in secondary schools (Rafeeq et al., 2021). A study known as "Effects of games in STEM education: a meta-analysis on the moderating role of student background characteristics" examined the differential effects of game intervention in STEM subjects on different groups of students and found moderate positive effects on motivation, cognition, and heterogeneity. Moreover, the moderator analyses showed that students of primary schools obtain higher learning outcomes when they are intervened in the gaming experience which is known as their motivating factor(Arztmann et al., 2022). A paper published in the journal of Contemporary Issues in Science and Technology Education, titled "STEM Education as a Meta-discipline" identified that STEM has removed the traditional barriers and focused on the solutions of contextual problems with innovation and

applied processes. In addition to it, STEM has acknowledged knowledge-intensive jobs, a culture of continued innovation, and economic prosperity in the future. The paper has also discussed the definitions of STEM, STEM education policy development in different countries, and the models of pedagogical implementation (Kennedy & Odell, 2023).

3. METHODOLOGY

In this study, an experimental approach has been used to identify the issues that teachers face in teaching the K-12 STEM subjects. After the collection of surveys from teachers as shown in Table I and Table II, the prototype application (Fig. 1-9) was shared with the teachers. Lastly, the surveys from Table III and Table IV were distributed with the teachers to find out the needed improvements and feasibility of using the prototype application in the future. The survey along with the prototype was distributed specifically to the teachers of secondary and higher secondary schools who were teaching STEM subjects.

3.1. Participants

For this research, the teachers were recruited based on the following criteria:

1. Working at two private schools based in Hyderabad, namely “St. Bonaventure’s High School” and “The City School”.
2. Minimum education of 14 years
3. Basic understanding and skills related to IT.
4. Teach STEM related subjects

3.2. Data Collection

The method for distributing the survey was used by Google Forms. The survey in “Table I” included a pre-analysis section in which teachers were initially asked about their learning and teaching methods and their level of education and IT skills. Table I shows the survey questions.

Table 1: Preliminary Survey

	Integrating Technology with Science in STEM Education for K-12 Students in Hyderabad			
	Question	**Option 1**	**Option 2**	**Option 3**
1	What is your highest education level?	14 year	16 year	18+ year
2	What domain do you teach?	Science, Technology, Engineering, or Mathematics		
3	Are you able to prepare your course for teaching?	Yes	No	To a little extent
4	Do you use any kind of technology to teach children?	Yes	No	
5	Are you familiar with basic IT-based learning/teaching?	Yes	No	To a little extent
6	What strategy do you mostly use to teach students?	Class board and marker	Projector	Verbal and Hand Gestures

	Integrating Technology with Science in STEM Education for K-12 Students in Hyderabad			
	Question	**Option 1**	**Option 2**	**Option 3**
7	Are you able to stimulate students' interest in your subject matter?	Yes	No	To a little extent
8	Are there any sort of computer devices/labs available in your institute?	Yes, there are computer labs	No, only for administration	
9	Would you prefer to teach students with an application that integrates your subject with the animation-based application?	Yes	No	Sometimes

After the pre-experimental survey, the prototype was shown to teachers in order to find out their understandability and interaction with technology for teaching their subjects. The prototype was developed using Adobe XD. Fig, 1-4 shows sign up, login, and initial interface of the application. It is an animation-based video application that provides options at the left and right columns to draw shapes and add in the animations which are available at the bottom. As shown in Fig. 5, the shapes are drawn representing how a molecule of water is formed, and upon adding the animations on joining the two atoms of Hydrogen with Oxygen, the lecture becomes interesting to understand how in a real time formation of molecule takes place. Similarly, Fig. 7 shows how in a real time a physical experiment of Newton's Third Law of Motion works, by drawing the shapes and adding animations, the backward reaction of rocket smoke and forward reaction of rocket helps in understanding how an opposite reaction takes place. Lastly, Fig 9 shows how to save an animated video in computer by clicking on the save option which will export the animated and can be used in the lectures.

The post-experimental section of the survey in Table II proposed another set of questions after the prototype (Fig. 1-9) was shown to teachers. Given are the images of the prototype model.

Fig.1. Welcome Page of Prototype

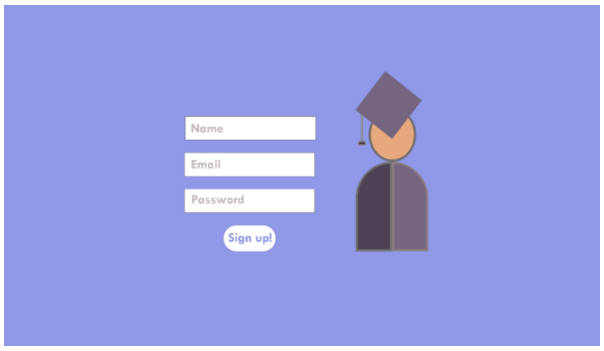

Fig.2.Sign up Page of Prototype

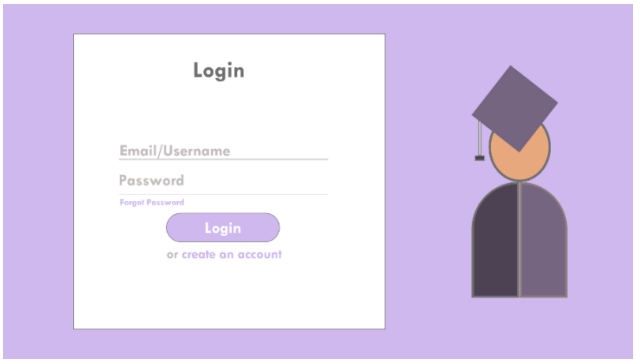

Fig.3. Login Page of Prototype

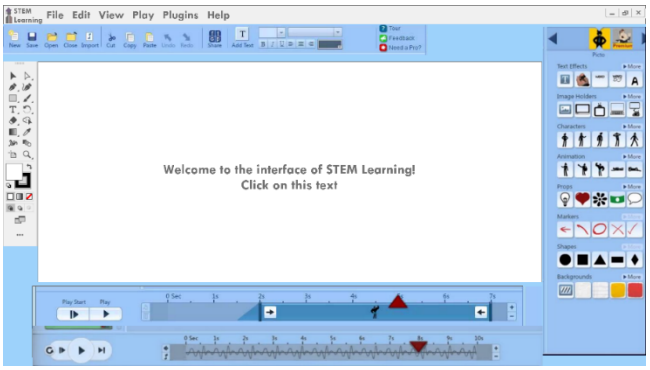

Fig.4.The User Interface of Prototype

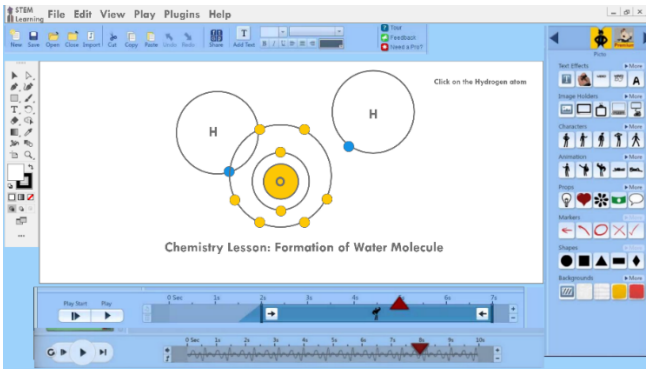

Fig.5.Creating animations to explain a chemistry lesson

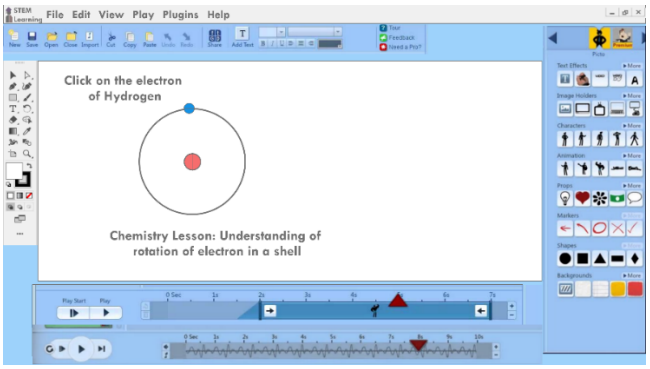

Fig.6.Another example of creating animation of a lecture.

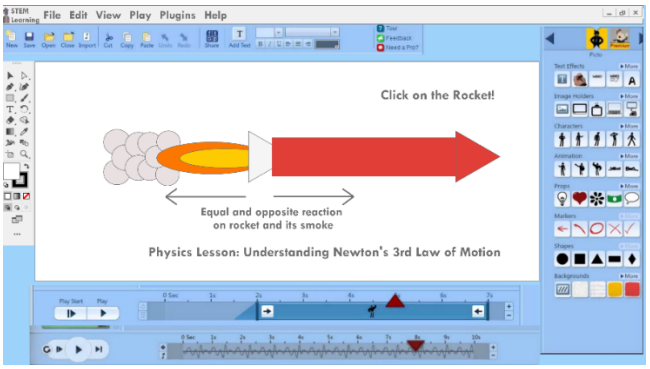

Fig.7.Another example showing a physical experiment

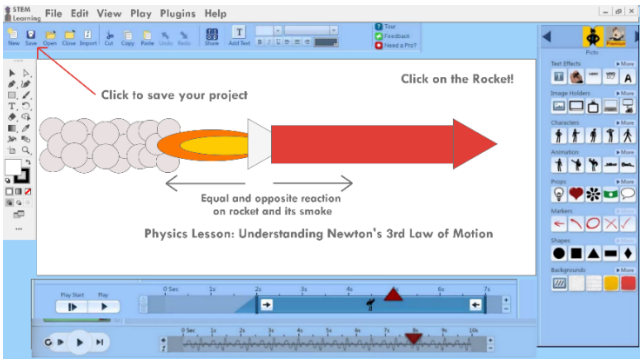

Fig.8.Continued to Figure 7

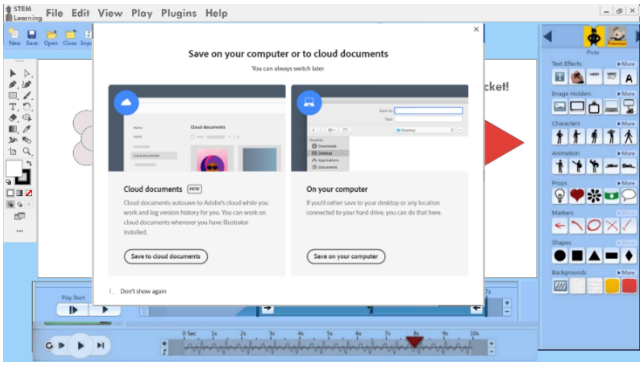

Fig.9.Shows how to save a video on a computer or cloud

The post-experimental survey questions are listed in Table 2 below:

Table 2: post-experimental Survey

	Integrating Technology with Science in STEM Education for K-12 Students in Hyderabad			
	Question	**Option 1**	**Option 2**	**Option 3**
1	Would you like an application that is user-friendly and interesting?	Yes	No	I cannot decide
2	Would you prefer to teach students with an application that integrates your subject with animation-based application?	Yes	No	
3	Would you like an animation-based drag-and-drop application like the one below that helps your students engage in your lecture?	Yes	No	
4	Rate the prototype application's interface.	Very Confusing-Confusing-Normal-Interesting-Very Interesting		
5	Rate the feasibility of drawing shapes for your lectures	Very Confusing-Confusing-Normal-Interesting-Very Interesting		
6	Rate the feasibility of adding animations for your lectures:	Very Confusing-Confusing-Normal-Interesting-Very Interesting		
7	If this application gets available freely in the market, would you use this in your future lectures?	Yes	No	Maybe
8	How often will you use this or other such applications in your teaching methods?	In every practical lecture	Only when I have time to prepare for it	will never use it

4. RESULTS

Given below are two tables Table III and Table IV which are the results of the survey. Table IV survey was distributed after the prototype application was evaluated by respondents.

Table 3: Preliminary Survey Results

	Integrating Technology with Science in STEM Education for K-12 Students in Hyderabad			
	Question	***Option 1***	***Option 2***	***Option 3***
1	What is your highest education level?	12.5% had 14 year	31.3% had 16 year	56.3% had 18+ year
2	What domain do you teach?	50% taught Science, 18.8% taught Technology, 31.3 % taught Engineering and Mathematics		
3	Are you able to prepare your course for teaching?	87.5% said yes	6.3% said no	6.3% said, to a little extent
4	Do you use any kind of technology to teach children?	75% said yes	25% said no	

	Integrating Technology with Science in STEM Education for K-12 Students in Hyderabad			
	Question	***Option 1***	***Option 2***	***Option 3***
5	Are you familiar with basic IT-based learning/teaching?	62.5% said yes	18.8% said no	18.8% said to a little extent
6	What strategy do you mostly use to teach students?	31.3% said class board and marker	62.5% said projector	6.3% said verbal and hand gestures
7	Are you able to stimulate students' interest in your subject matter?	87.5% yes	12.5% said no	
8	Are there any sort of computer devices/labs available in your institute?	87.5% said yes, there are computer labs	12.5% said no, only for administration	
9	Would you prefer to teach students with an application that integrates your subject with the animation-based application?	81.3% said yes	18.8% said no	

Table 4: post-experimental survey results

	Integrating Technology with Science in STEM Education for K-12 Students in Hyderabad			
	Question	***Option 1***	***Option 2***	***Option 3***
1	Would you like an application that is user-friendly and interesting?	100% of respondents said yes		
2	Would you prefer to teach students with an application that integrates your subject with an animation-based application?	100% of respondents said yes		
3	Would you like an animation-based drag-and-drop application like the one below that helps your students engage in your lecture?	100% of respondents said yes		
4	Rate the prototype application's interface.	6.3% said very confusing, 12.5% said confusing, 12.5% said normal, 25% said interesting, 43.8% said very interesting		
5	Rate the feasibility of drawing shapes for your lectures	18.8% said confusing, 12.5% said normal, 31.3% said interesting, 37.5% said very Interesting		
6	Rate the feasibility of adding animations for your lectures:	6.3% said confusing, 18.8% said normal, 31.3% said interesting, 43.8% very interesting		

	Integrating Technology with Science in STEM Education for K-12 Students in Hyderabad			
	Question	***Option 1***	***Option 2***	***Option 3***
7	If this application gets available freely in the market, would you use this in your future lectures?	68.8% said yes	6.3% said no	25% said maybe
8	How often will you use this or other such applications in your teaching methods?	75% said in every practical lecture	25% said only when I have time to prepare for it	

5. DISCUSSIONS

The following discussion based on the survey results from Table III and Table IV were of prime importance because these results showed varied answers from different teachers of varied education backgrounds, schools' modern teaching methods, and IT skills. Each question below holds an explanation for the varied results of the respondents.

Q.1 What strategy/technology do you mostly use to teach your children? (result taken from Table III)

Answer: The survey results showed that 62.5% of the audience used projectors while 31.3% relied on class board and marker. Only 6.3% audience were those who used non of the technology/strategy except hand gestures. This showed that the audience who used projectors were those who had higher education level and taught technology and science subjects. The 31.3% audience were those who had 14 years of education and had less IT skills. This shows that greater education qualification and IT skills are mandatory for teaching STEM education.

Q.2 Are there any sort of computer devices/labs available in your institute? (result taken from Table IV)

Answer: 87.5% of the respondents showed that there were computers and projectors available, while the remaining percentage such as 12.5% showed that the devices were only available for administration use. Due to the unavailability of basic computing devices, teachers might have to use their personal devices to prepare their lectures from the prototype application. On the other hand, if there are no computer devices, students will only get lectures from teachers by verbal or hand gestures and class board and marker. However, in an era of emerging technologies, the government or education institutes must provide IT devices in academic learning for producing modern teaching methods.

Q.3 Rate the prototype application's interface. (result taken from Table IV)

Answer: The results showed an average understanding of the prototype interface and usability for teachers, the percentage was about 43.8% voted for an interesting interface of the prototype application. The remaining percentages for normal and confusing ratings show the reason that the teachers were found to use none of the IT-based teaching methods nor had skills to use basic IT software. On the other hand, those higher percentages of respondents show that teachers who have 16 years of education background with good skills in IT rated the prototype interface as very interesting and user-friendly to draw shapes and designing

animation-based topics. As a result, there is yet a crucial need for teachers to acquire IT skills to have a fundamental understanding of computers and teaching software.

Q.4 How often will you use this or other such applications in your teaching methods? (result taken from Table IV)

Answer: Even though 75% of teachers were likely to use this prototype application in the practical demonstration of their lectures, however, the remaining percentages which were about 25% showed that teachers would only use this application when they will have time to prepare their lectures. As a result, this is not a sustainable option when it comes to teaching K-12 students. Teachers must be held accountable for their teaching styles and the interest of students in their lectures.

6. RESEARCH LIMITATION

The limitation was found in collecting literature review of STEM education of K-12 schools in Hyderabad. The reason for it is that most of the teaching methods were outdated and not inspected, as a result, no research was found to be collected for education and teaching methods of K-12 grades. Moreover, there was no or less use of technology-based learning in the schools. In addition to it, the survey distribution became an unapproachable issue for the K-12 teachers, because the teachers were found to have no interaction and use of technology or email accounts. On the other hand, the results of the survey denoted that due to less education levels of teachers, they were not able to understand the prototype model of the application.

The results of this study are based on the recruitment of teachers teaching STEM related subjects at two private schools in the city of Hyderabad, Pakistan. These can be considered as the limitation of the current study.

7. FUTURE WORK

The future work for this study is needed to be expanded in the area of STEM education-based applications that stimulate the interests of teachers as well as students. Future developers and analysts are required to improve the STEM education learning application and develop the prototype which needs to be distributed among the targeted audience to help them get familiar with STEM education and promote it within the K-12 education institutions.

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