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Research Article

Investigating the Effects of Horizontal Transition with Student-Preferred Learning Materials in a Virtual Biology Laboratory

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Abstract: Adaptive Virtual Learning Environments (VLEs) present customized teaching materials to individual students which help them to achieve their learning goals and serve quite a vital role in virtual learning environments. In this paper, we present a new student-centered learning approach in a three-dimensional (3D) virtual biology laboratory (VBIOLAB). The approach is based on the concept of horizontal transition with student preference (HTWSP) implemented with the help of VBIOLAB. The HTWSP is based on the concept of allowing students to choose their preferred learning styles according to their needs and pace instead of automatically adapted aids. HTWSP allows students to stay in a certain module and attain more information about that learning module through various aids of their choice. To go to the next learning module there is a mechanism of vertical transition which allows a student to make quick progress by skipping the details about a certain module. Intermediate-level students participated in experiments that compared the proposed system with an adaptive virtual laboratory. Experimental results indicated that 75% of students improved their examination scores through the use of VBIOLAB. Data from the system usability scale (SUS) and the subjective rating supported greater participation, motivation, and effectiveness in learning using VBIOLAB. The experimental results reveal that this approach is effective and vital to utilize to enhance students' learning in 3D-VLEs.

Keywords: Virtual Reality, Virtual Learning Environment, Virtual Biology Laboratory, Learning Approach, Student Learning Styles, Horizontal Transition, Vertical Transition.

1. INTRODUCTION

Virtual Reality (VR) technologies allow users to immerse themselves in the interactive simulation system through visual, auditory, and tactile feedback. VR uses 3D graphics and sensors to generate realistic virtual environments and get objects that are processed and controlled by computers [1]. The multi-sensory interactive nature of VR allows it to be widely used in various fields, i.e. Artificial Intelligence and machine learning, education and E-Learning, healthcare and medicine, software development, edutainment, robotics, and autonomous systems and training. Numerous concepts are taught through VR applications [2]. For gaining scientific knowledge, laboratories are imperative in every field of science. Laboratories provide opportunities for building skills and learning experimental work. Physical labs need many resources i.e. place, apparatuses, and workforce. Virtual labs eliminate all these requirements. Laboratories provide replicas of physical labs and help to increase learning experiences [3]. Virtual laboratories allow students to perform experiments similar to conventional labs and to gain experience in laboratory work. Students are permitted to perform experiments without any fear of making mistakes because they can fix them by revising the experiment and thus their inquisition and commitment to learning is increased [4].

The continued development in computer graphics and virtual reality can provide the opportunity to rapidly expand the use of virtual laboratory applications which ultimately decrease the need for real-world laboratories [5]. Customized

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teaching materials for different students result in enhanced learning which improves students' performance in 3D-VLEs [6]. Adaptive 3D-VLE can alter its materials for different students because their learning strategies vary, which contributes to improving their learning [7]. Changing the contents of 3-Dimensional Virtual Learning Environments is a difficult task because of no clear strategy for specific learners [8].

In anatomy teaching, it is observed that with the traditional approach, students do not get enough opportunities to achieve learning objectives. Theoretical, 2D PowerPoint presentations and other traditional aids are not sufficient for their future learning provisions. 3D-VLEs about anatomy provide innovation and ease of interactivity with bones, muscles, and other organs. Users can manipulate them and it contributes to increasing their performance significantly [5]. Various studies conclude that students, who were taught through 3D animated programs of various body parts, took decent grades in contrast with 2D PowerPoint presentations [9]. Seo *et al.* [10] developed the Anatomy Builder VR application, to examine how a constructivist method can support anatomy education while using VR technology actively and experimentally. Traditional VLEs are not capable of properly administering the diverse requirements of students and this issue can be solved by adaptability. Adaptive 3D-VLEs can alter their materials for different students because their learning strategies vary the adaptivity contributes to improving their learning [7]. Byukusenge *et al.* [11] investigate the effect of virtual laboratories on student performance in learning Biology education. The results show significant improvement in upper secondary students' attitudes and performance in challenging biology topics.

Customized teaching materials for individual students prevent them from amiss steering in the virtual world and provide a means of differentiation between knowledge and merriment [12]. Designing a system in which the adaptivity of the learning material of considering the student's properties is still a challenging job [7]. For teaching anatomy in a 3D VLE, direct manipulation is better than passively viewing a certain structure. The result of the two groups suggests that direct manipulation through a haptic virtual device group achieved higher grades as compared to the passive viewer group [13]. Students learn better when their learning style matches with their teacher's style [7]. According to Cristina *et al.* [14], simulations in virtual laboratories are deemed most effective as preparatory tools rather than replacements for traditional labs.

There are substantial connections between students' achievements and their learning techniques [12]. An and Carr [15] present individual differences as the alternative solution to learning styles and suggest teachers consider the various variables of individual differences, i.e., verbal and visual skills, expertise, self-regulation, etc. The study conducted by Tsirulnikov *et al*. [16] found that immersive virtual reality laboratory simulations using head-mounted displays effectively enhanced undergraduate students' learning outcomes and motivation. Reisoglu *et al.* [17] compared various learning strategies inside a VLE and concluded that learners prefer collaborative learning strategy and exploration-based learning strategy. Other strategies were role-playing; problem-based learning, learning by doing, etc. They asserted that collaborative and exploration-based learning strategies were preferred in learning support environments. The Traditional educational methods of learning are teacher-centered and students have different knowledge levels individually and usually, they are incapable of obtaining the effective usage of the teaching methods to upsurge their knowledge alike. Very little attention is given to resolving the concentration issues that arise during the delivery of learning materials for each student. Gunathilaka *et al.* [18], worked on an approach that they call the Individual learning path personalization approach. The learning materials are changed dynamically according to the knowledge levels of the learner and learning styles in a VLE. They distributed the learning materials in personalized paths and in a student-preferred way. They calculated their preferences in terms of knowledge levels, and dynamic and static learning behavior of the student, and lesson contents are delivered accordingly. It is observed that the learning path personalization according to the knowledge level and the style affects learning positively and their performance increases as compared to the group who did not use this VLE. Alshammari [19] worked on an adaptive approach that incorporates learning style and student performance to produce personalized learning paths as the main adaptive feature. These variables were identified through questionnaires from students to determine the value and type in the learning style dimension for each student. To represent the perception dimension of learning style in the student model, they assigned the students to one of the defined four stereotypes; students having strong or moderate sensory style, mild sensory style, mild intuitive style, and strong or moderate intuitive style. They tracked the students' performance through quizzes and dynamic student-system interaction which classified the knowledge level into one of four degrees including: unknown, partially learned, learned, and mastered. They experimented with two groups, one with the traditional approach and the other with their proposed approach, and concluded that the adaptive approach was effective. Alam and Ullah [7] presented the idea of horizontal transition for adaptive VLE in which information is presented in the form of figures, graphs, or tables. It provides an opportunity for students to realize the required learning topics by providing additional information about a certain topic and staying more in a learning module, consequently, a weak learner can benefit from this. Also, there is a mechanism of vertical transition which is for good learners to quickly progress by providing the next module with less detail. These transitions are decided by a learning decision function (LDF) that takes a student's score, no. of errors, and time as input and automatically decides the next step of learning for the student. Teaching materials at the next level occur according to the previous performance of the student [6]. The system provides detailed information in customized paths through figures, graphs, or tables. It provides detailed information to weak students and stays in the same learning module. For good students, it shows abstract information in the next module. A good learner may need more information at the next level and may face problems as the adaptive criteria "learning skill" does not handle this situation. There is a need for a proper framework to improve horizontal transition; also there is a need for different learning styles and materials. Most importantly, students should be allowed to make transitions according to their needs and preferred learning styles.

Current approaches are based on automatic adaptation based on performance or by predefined stereotypes. However, these approaches prevent the independence of students from regulating transition and their learning trajectories. Students have problems with automatic adaptations that are not based on their preferences and requirements. In this paper, we developed a new learning approach called Horizontal Transition with Student Preference (HTWSP). The proposed HTWSP presents customized teaching materials to each student as per his/her preference and pace. HTWSP provides an opportunity for students to obtain information following their favored learning styles in the Virtual Biology Laboratory (VBIOLAB). Horizantal Transition (HT) had the learning skill as the transition strategy to the next level which was decided automatically by students' performance in the previous level. We have noticed that students have problems with its automatic adaptation. In our approach, the student has the facility to adaptively perform transition to the next level as per their needs.

2. MATERIAL AND METHODS

2.1. Virtual Biology Laboratory (VBIOLAB)

VBIOLAB is a 3D virtual environment that extends the advantages and benefits of HTWSP. In VBIOLAB we have added more learning materials i.e. text, 3D models, graphical information, and animated videos. Students get detailed information about the experiment through these aids and make transitions according to their preference, which improves their learning proficiencies.

VBIOLAB is a desktop application made with Unity 3D which uses a mouse and keyboard for navigation in the VE. User can select their choice of aids for experimenting and move around through the keyboard. It is a game-like environment in which the mouse has the camera viewpoint. The proposed simulated environment is shown in Figure 1.

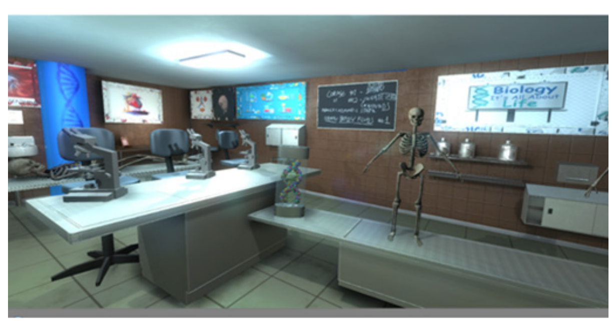

Fig. 1. The inside scenario of VBIOLAB.

Our VBIOLAB provides some advantages over previous virtual applications:

- Unlike PowerPoint presentations, it provides a 3D interactive environment that enables the user to experience more immersion.
- It provides the facility of different learning styles to ease students learning during the experiment.
- Through various learning aids; text, 3D virtual models, graphical information, and animated videos, students can easily perform experiments in VBIOLAB.
- The learning approach HTWSP helps students to perform the experiments in VBIOLAB according to their preference.
- It resolves the issues of HT by providing the transition facility to the students instead of the automatic allocation of aids.

2.2. VBIOLAB Implementation

The VBIOLAB was implemented in Unity3D 5.6.1f1 using C# on an HP Corei3 Laptop having a specification 2.9 GHz processor, 4 GB RAM, Intel (R) HD Graphics card, and Windows 7 (64-bits) operating system. We used a Mouse and keyboard for interaction with the environment. The proposed system works on the learning approach HTWSP. To investigate the efficiency of the proposed system we also utilized the 3D application Multi Model Virtual Chemistry Lab (MMVCL) developed for HT [6, 7]. It has learning materials in the form of slides which is based on the adaptive learning approach of horizontal transition.

2.3. Experimental Protocol

To conduct the experiments, 40 students (20 males and 20 females) of intermediate level from 10 different institutions having ages between 17 to 19 years were randomly selected for evaluation. Students were divided into two groups (G1 and G2), each one had 20 males and 20 females. All students were familiar with gaming, using a keyboard, mouse, and touchscreen but they had no experience with VLEs. G1 was assigned the HT system implemented through MMVCL while G2 was trained on the HTWSP system implemented through VBIOLAB for experiments. All students were briefed about their assigned system. They were also directed about the selection of different aids and interaction with the models. The MMVCL has learning materials in the form of slides, tables, and graphs and is based on the learning approach of HT. The learning materials were altered to our topic taken from biology "Identification of various bones of the human skeleton". MMVCL and VBIOLAB systems were installed on systems during experimentation. Students were asked to perform experiments on both systems and give a subjective test for each of them. We also evaluated the system usability scale (SUS) of both systems. At the final step questionnaire was provided to the students for evaluation for both approaches. In HTWSP system the experiment "Identification of various bones of Human skeleton" was experimented. We have selected four modules; skull and ribs from the axial skeleton and upper limb and lower limb from the appendicular skeleton. Students in G2 experimented with VBIOLAB utilizing multiple aids of their choice with the HTWSP approach while those in G1 used the learning approach of HT.

2.4. Horizontal Transition with Student Preference (HTWSP)

The proposed learning approach HTWSP is based on the concept of allowing students to choose their preferred learning styles according to their needs and pace. This approach allows each student to select his own choice of learning materials instead of automatically adapted aids. We have worked on the presumed learning approach to solve the problems of learners in many ways. We have provided detailed information in the form of aids i.e. textual, graphical, 3D models related to the experimental modules, and animated video. Categorizing students and providing details to each student according to his performance in the previous module creates confusion and students need more information in the next module. The proposed learning approach eliminates this issue by providing an aid selection facility to the students. Thus weak and good students can participate more dynamically and achieve learning objectives suitably. HTWSP allows students to stay in a certain module and attain more information about that learning module through various aids of their choice. To go to the next learning module there is a mechanism of vertical transition which allows a student to make quick progress by skipping the details about a certain module. Students are allowed to make the vertical transition to their preference, thus good students are prevented from being overwhelmed. Figure 2 shows the proposed system architecture.

The description of each Module of the proposed system is explained below.

- **Start**
  The process begins here, initiating the learning system.
- **Learning Module M**
  This is the first learning module where students engage with the material. It provides foundational knowledge or concepts to the learners.
- **User Input**
  After interacting with Learning Module M, the system collects feedback or input from the student regarding their learning progress, preferences, or needs.
- **User Decision**
  Based on the input, the student chooses how to proceed. This decision determines the type of transition (horizontal or vertical) and subsequent actions.
- **Repeat with Different Aid(s)**
  The student continues with the revised module until they are satisfied with their understanding.
- **End**
  The learning process concludes here after the student completes all required modules and transitions.

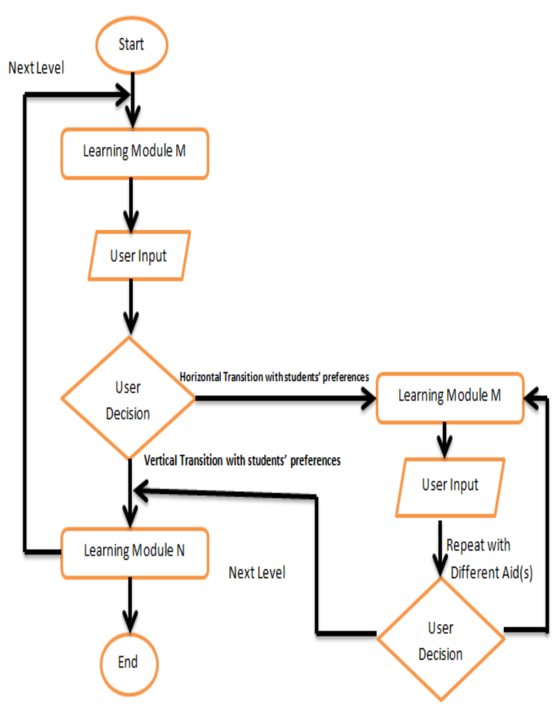

Fig. 2. The proposed system architecture.

3. RESULTS AND DISCUSSION

3.1. Students' Learning

This section presents the results of the tests after experiments conducted on HT and proposed systems for students. The experimental results show that 75% of students got high marks using the HTWSP system, while 10 % of students got lower marks on the HTWSP system as compared to the HT system. Similarly, 15% of students got the same marks while conducting experiments on HT and HTWSP systems. The overall result showed improved student performance in terms of mean and standard deviation (STD) of marks obtained. The mean and STD of the HT system were 64.75 and 16.02. The mean and STD of the HTWSP system were 77.5 and 14.97. Figure 3 illustrates the results of both systems in terms of mean and standard deviation.

3.2. Standard Usability Scale (SUS) Analysis

The system usability scale (SUS) is an efficient tool for measuring the subjective view of the usability of a system. It provides a high-level measurement of subjective usability. It proved to be a valid and reliable tool for analyzing the usability of systems and can be used for a variety of systems and types of technologies i.e. hardware, software, websites, business software, cell phones, apps, etc. Particularly, SUS can be used to compare two versions of an application that are centered on diverse technologies [20]. A SUS score of 68 or higher is generally considered acceptable usability. We compared the HT and HTWSP virtual applications through SUS by providing the SUS templates to the students. 40 students participated in the evaluation

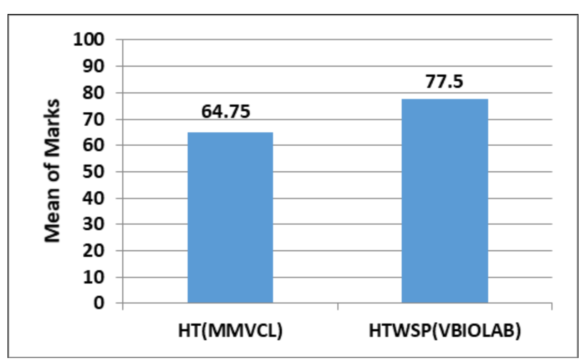

Fig. 3. Mean and STD of students' marks on both systems.

process and provided their opinions about both systems after performing experiments. For HT, the average SUS score was 71.25 while HTWSP average SUS score was 79.75 which indicates the efficiency and reliability of the proposed system. Figure 4 illustrates the SUS scores.

3.3. Subjective Evaluation

We distributed a questionnaire among 40 students for subjective evaluation of the HTWSP system. Table 1 shows the questionnaire which consists of five questions in which Q1,Q2 and Q3 are related to the efficiency of the HTWSP system. Figure 5 shows students' responses for Q1, Q2, and Q3 on a scale of 5 points. Q4 is about the prefered learning approach, for which students responses are shown in Figure 6. Q5 is related to the system attributes of both virtual environments which are given in Table 2. Students were asked about the proposed learning approach HTWSP and if it provided the student's choice of learning style. 60% of students marked it strongly agree, 25% agreed, 10% were neutral and 5% disagreed. The next question was about the freedom of selection and repetition of aids in the proposed system in contrast with the HT system. 65% selected strongly agreed, 30% agreed, 3% were neutral and 2% disagreed. In the HT, aids were provided automatically to the students for the next learning module, thus students were asked about the manual aid selection facility of the HTWSP. 58% selected strongly agree, 26% were agree, 6% were neutral and 10% were disagree as shown in Figure 5. The fourth question (Q4) was about both learning approaches. Students were asked about their preferred learning approach. 88% preferred the proposed learning approach "HTWSP" while 12% were in favor of the "HT" (see Figure 6).

3.4. Comparative Analysis

In Q5 we provided a table comprised of 8 questions to inquire students about environments of HT and

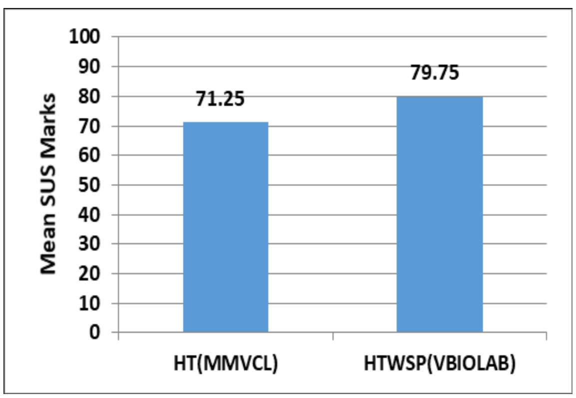

Fig. 4. SUS results of both systems**.**

Table 1. List of questions.

S. No.	Questions
1	The HTWSP provides learning styles according to the student's choice.
2	In contrast with the HT (MMVCL), the HTWSP (VBIOLAB) eliminates the concerns of time-bound and non-repeatable aid issues.
3	Instead of an automatic adaptation of teaching materials for the next learning module, the HTWSP was more effective.
4	You have utilized both learning approaches; HT and the HTWSP, which learning approach will you prefer?
5	Comparative analysis of system attributes

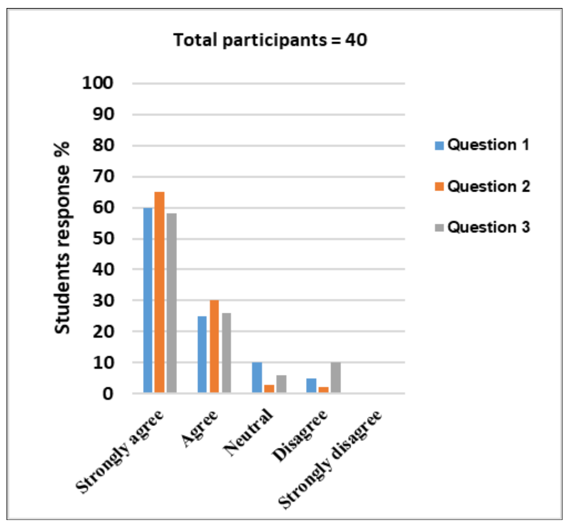

Fig. 5. Students' response for Q1, Q2 and Q3.

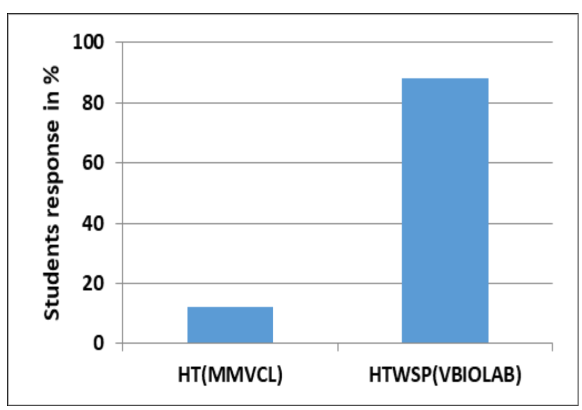

Fig. 6. Students prepared learning approach.

HTWSP systems. Table 2 shows questions related to the comparison of various attributes. For the first attribute, 81% of students marked the proposed system while 19% of students were in favor of the HT. For the second attribute, 84% marked the HTWSP system and 16% marked the HT. 83% of students marked the HTWSP for the third attribute and 17% marked the HT system. For the fourth attribute, 75% were in favor of the HTWSP system while 25% marked the HT system. For the fifth attribute, 80% marked the HTWSP and 20% preferred the HT. For the sixth attribute, 82% of students marked the HT to be intricate in transitions while 18 % marked the HTWSP system. For the seventh attribute, 76% were in favor of the HTWSP system and 24% selected the HT system. For the last attribute, 78% of students marked the HTWSP system to be student-friendly while 22% marked the HT system as shown in Figure 7.

From the overall results, it is clear that HTWSP significantly improved the learning performance of students and system usability, with 75% of students achieving higher marks and a mean score of 77.5 compared to 64.75 in the previous system. SUS scores favored the proposed system (79.75 vs. 71.25), and 88% of students preferred its customizable and student-centered approach. Most of the students (81-84%) found it more user-friendly, motivating, and efficient across various attributes, highlighting its efficiency over the old system.

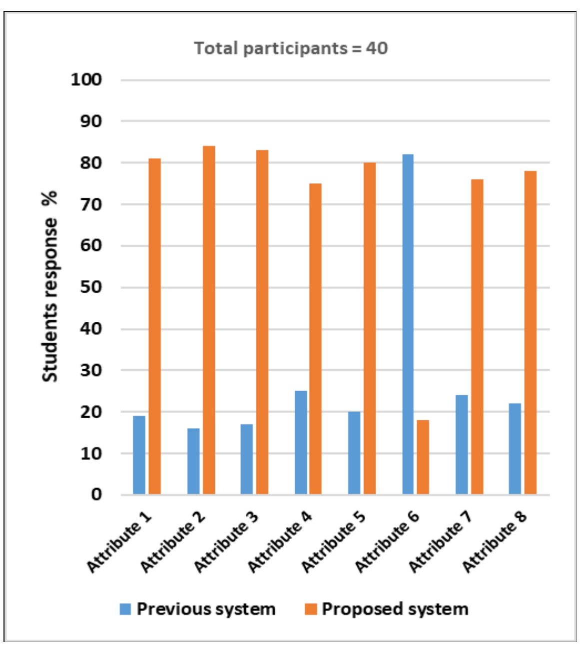

Fig.7. Comparison of HT and HTWSP systems.

Table 2. Comparative analysis of various system attributes.

S. No.	Attribute
1	The System Provides a Better Interaction Interface for Learning
2	The System Provides a More Natural Environment for Learning
3	The System Provides Ease of Navigation in the Virtual Environment
4	The System Provides Efficient Learning Materials and Models
5	The System Motivation Students Towards Learning
6	Intricate Horizontal and Vertical Transitions
7	Overall Efficiency of the system
8	The System is Student Friendly

The results of the statistical assessment and subjective evaluation proved that all the participants could accomplish their tasks in a short time by using VBIOLAB. VBIOLAB is an efficient application for familiarizing students with biology experiments and it can overcome the problems that are faced in educational institutions related to biology laboratories, i.e., space, equipment, and time. VBIOLAB provides students with an advanced 3D interactive environment, 3D models, textual, graphical, and animated video aids, and the freedom to select from these aids. We have provided an effective learning approach that delivers detailed and repeatable information through various aids that the students prefer. Experiments show that HTWSP improves students' learning skills and they take more interest in biology learning. The textual, graphical, 3D models, and animated video information are very helpful for students in improving their grades. Through different learning styles in VBIOLAB, they can perform their experiments without their teacher. The feedback of the participants also proved that the VBIOLAB is easy to use and easy to understand. All participants also endorsed that VBIOLAB is very useful and suitable for biology teachers and students because it provides a realistic virtual environment and facilitates the experimental process. VBIOLAB is an efficient tool for educational institutions to adopt as a replacement for the real lab which addresses the limitations of physical labs.

4. CONCLUSIONS

In this study, a key issue "the lack of adaptability to individual student needs and preferences" is addressed. Previous adaptive virtual environments provide automatic transitions between modules, leaving little space for student autonomy and preferred learning styles. To address this problem, we developed and tested the HTWSP approach, integrated into the VBIOLAB. Our developed application is very helpful for educational institutions where students can perform their biology experiments in a real-world biology laboratory. We have provided an effective learning approach inside a virtual biology laboratory to enhance students' learning. We conducted different tests on students to find the expediency and competence of the VBIOLAB and the learning approach HTWSP. Experimental results demonstrate that 75% of students improved their examination scores using VBIOLAB. The mean examination scores and system usability scale (SUS) ratings for VBIOLAB surpassed the HT system [6]. Moreover, in subjective evaluations, 88% of students preferred the HTWSP system. Overall evaluations prove that the HTWSP implemented through VBIOLAB is a very useful and efficient application for biology practical learning and the user can easily understand and use the system. HTWSP proved to be an effective learning approach. Providing different learning styles with the advantage of free selection among these aids greatly enhances students' curiosity and performance. Compared to previous works of researchers our system is very easy and flexible in usage, understanding the environment, performing the experiment with ease, and improving learning. The system's performance was tested on a specific setup, and factors like cultural differences or student-selected learning paths may affect consistency and applicability.

5. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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