RESEARCH ARTICLE

SAMRIDDHI Volume 13, Issue 1, 2021 Print ISSN: 2229-7111 Online ISSN: 2454–5767

Understanding Concepts of Physics through Virtual Labs during Lockdown

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Abstract

In the past years, virtual lab software applications seem to be adopted everywhere in the education world. Physical Labs play a vital role in the learning of physics. This study aims to introduce a systematic platform of experiments that are practically not possible to conduct in our physical labs. Here, we are presenting an overview of virtual labs in the field of relativity. Here, the user can experience real-time relativity (RTR) while sitting in the classrooms. Keeping in mind that students get the full liberty of committing mistakes, we are designing the experiment in the same manner. An evaluation system is being introduced to monitor the understanding of students in the respective lab. This evaluation system consists of pre and pro-test. These tests consist of multiple-choice questions (MCQs) and problems on the particular subject area. After successful completion of the experiment, Users get awarded a certificate to merit his/her performance. This paper presents the virtual lab concept on time dilation effect and ultimately simulates the same in a relativistic virtual environment. In the future, the same method could be employed to study other relativistic phenomena virtually using a virtual lab.

Keywords: Physical labs, Real-time relativity, MCQs, Virtual lab

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology (2021); DOI: 10.18090/samriddhi.v13i01.4

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How to cite this article: Dixit, A., Shukla, A.,(2021). Understanding Concepts of Physics through Virtual Labs during Lockdown *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology,* 13(1), 12-19.

Source of support: Nil

Conflict of interest: None

As we know, the study of nature and properties of matter and energy is the primary concern of Physics. It includes studying universal laws and the behaviors and relationships among various physical concepts and phenomena. Theory and experiment are the two different aspects required to be studied while understanding any physical phenomenon. Experiments play an essential role in enhancing the understanding of the subject. One of its essential roles is to test theories and to provide the base for scientific knowledge. Effective practical physics enables learners to understand the connection between what can be observed and handled (hands-on) and scientific ideas that inform their observations (brains-on). Through practical activities, it is much easier to thread the connection between actions and observations. Students can observe and understand the scientific phenomena happening around in a better way by performing experiments in the physics lab, which helps develop their scientific attitude and vision. Learning through experiments helps in bridging the gap between concepts and phenomena. Present work helps in understanding the two different aspects of theory and lab. At first, we are proposing only one experiment and the aim of the present study is to enhance experimental methodology in different domains of Physics. We propose a complete course of virtual lab on *"Special Theory of Relativity"* in further studies.

For experiments to perform, we need well-equipped laboratories. At the same time, lab experiments have traditionally suffered from numerous constraints that limit their external validity. Traditional laboratories have many more limitations and problems, and due to these limitations, today's conventional laboratories and the experiences acquired are not meant for students and do not make a non-trivial contribution to the conceptual understanding of students (Yager et al., 1969). Students execute experiments in the laboratory to develop low-level science skills (Hofstein &Vincent, 2004).In a study(Nazlia, RozliZulkifli,& Rosilah, 2004) on problems during physics lab sessions, the observation taken has been depicted in Figure 1. 17% of the students lacked performing skills, while 16% of the students lacked preparation. 15% was limited lab equipment factor, and another 15% was due to incompetent lab demonstrators. These factors may hamper them from successfully acquiring

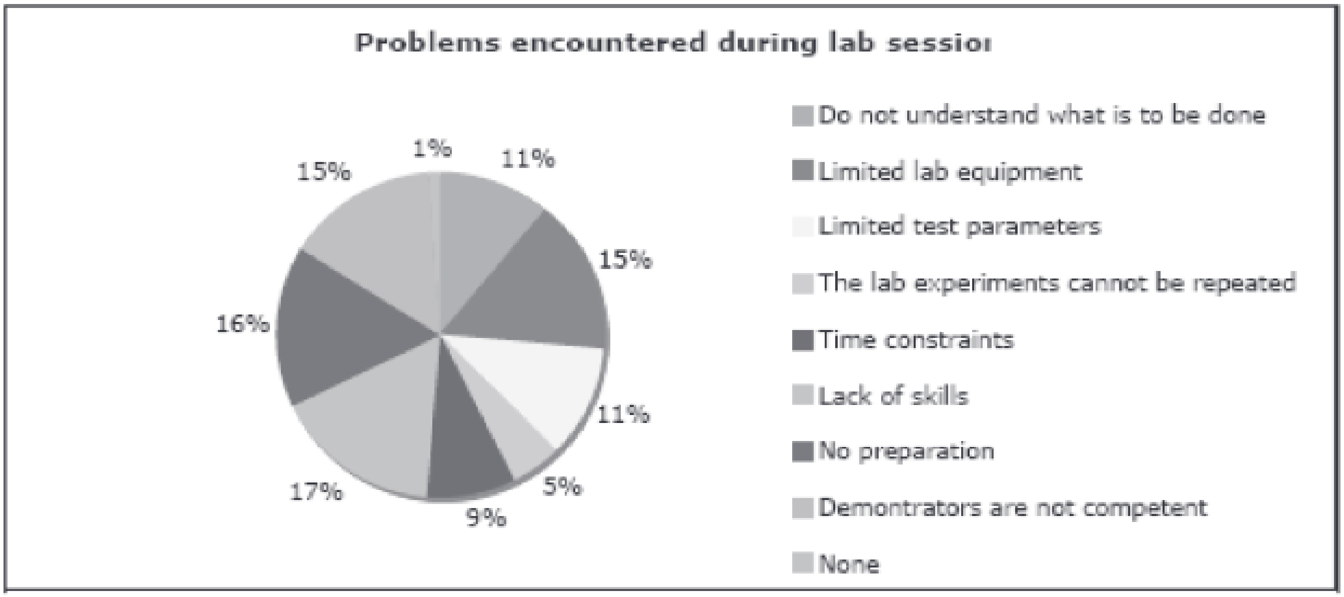

Figure 1: Results on related problems during lab sessions

the key concepts and knowledge predictable from the experiments performed.

Keeping in mind the problems of outmoded physics lab, a new concept of laboratories is needed to construct their knowledge (Wentling & Park, 2002) actively. In the present scenario, teaching physics via a computer simulation-based method using a virtual lab is an emergent controlling method of experimentation outside the laboratory. All physics experiments, which were being conducted in physical labs previously, could be performed on a computer over a virtual labFurthermore, virtual labs have additional safety features, as there is no exposure to potentially harmful apparatus (e.g., lasers) and decreased period to accomplish the laboratory assignment (Toth, Ludvico, & Morrow, 2014).

According to a study report submitted to the Government of India (2011), in India, A project of Virtual Labs, an initiative of the Ministry of Human Resource Development (MHRD) Government of India, under the flagship of National Mission on Education via Information and Communication Technology. The project aims to provide remote access to Laboratories in various streams of science and engineering for students at different levels from undergraduate to research (Callaghan, Harkin, & Maguire,2007). Seven IIT's (Delhi, Bombay, Kanpur, Kharagpur, Madras, Roorkee, and Guwahati), IIIT Hyderabad, Amrita University, Dayal bagh University, NIT Karnataka, and College of Engineering, Pune, are the institutions participating in the project.

Revolution in information & communication technology has opened wonderful openings for enhancing the quality of education. The Virtual laboratory serves as a computer-based numerical laboratory for teaching Physics and other experimental subjects. It consists of logically interconnected learning (Lhagva et al., 2005; Lhagva et al., 2011) to help learners.

Rapid science inventions in the 21st century have enhanced technological expansions, which have paid to the development of countries (Fishbane, Gasiorowicz, & Thornton, 2003). Basic sciences play an important role; hence, countries that do not want to lag in the technological struggle have concentrated on raising well-educated analytical and productive individuals in basic sciences (Çalı! kan, Selçuk, & Erol, 2012). However, physics is the most challenging for students (Arvind & Heard, 2010). As, most physics concepts are intellectual (Jian & Hong, 2012). hence, it is most challenging to understand. In physics courses, it is critical to correlate abstract concepts with real-life events, tedious mathematical problems are eradicated, and lab practice's weight is increased (Çelik & Karamustafao,2016; Papanastasiou, Drigas, & Skianis, 2017). The laboratory that empowers permanent learning is a place/medium where students learn through performing individual tasks or in small groups (Lateh, & Vasugiammai, 2011). However, the physical laboratories can't be used efficiently for several reasons, like not every school has proper equipment setups, and their cost to set them up and maintain and the lack of equipment (Tatlı & Ayas, 2011). Usually, most of the students cannot understand the theoretical concept through a lab experiment, they wrote it and, as a consequence, learn nothing and it results in their failure. After facing failure, a negative approach is developed among the students towards the course, and they start losing their interest in that subject domain (Trundle & Bell, 2010). To resolve the difficulties, virtual laboratories came into the picture (Trundle & Bell, 2010).

Simulations are a hi-tech tool that can transform theoretical knowledge into skills for educational purposes (Rutten et al., 2012). These are the software programs that imitate the basic components of the real world to deliver controlled learning environments (Colace, De Santo, & Greco, 2014). There are many educational benefits of using virtual laboratories over existing physical ones (Rutten et al., 2012). Some of the benefits are reducing time interval of experiments, performing dangerous experiments in a harmless environment, reconstructing virtual measures that are impossible to be observed in the physical laboratory, an alternative solution for expensive laboratories, empowering students to progress at their own pace, and providing them with immediate feedback to check their learning (Smetana & Bell, 2012; Rotimi, Ajogbeje, & Akeju, 2012; Rutten et al., 2012; Tatlı & Ayas, 2011; Trundle & Bell, 2010; Fiscarelli, Bizelli, & Fiscarelli, 2013; Zabunov, 2013). In literature, there is a good collection of studies on virtual laboratories for physics lab courses (Saldikov et al.,2017; Wang,2013; Dinçer& Güçlü,2013)

Virtual labs could be developed to provide a complete Learning Management System in which the students can take advantage of the various learning tools, including additional web resources, video lectures, animated demonstrations, and self-evaluation. Furthermore, through this virtual lab platform, one can share expensive equipment and assets accessible to only a restricted number of users due to limitations on time and geographical distances.

How Virtual Labs Affect Understanding Level of Users?

Undoubtedly, Virtual Labs cannot replace physical labs, but at the same time, Virtual labs can be a raised area by which we can enhance the understanding level of the users. He/She must be able to evaluate their level of considerate. In table 1, the merits of the virtual lab have been shown. The understanding of the topic of time dilation using theory and the virtual lab has also been discussed.

Objectives Of Proposed Lab

- To understand the concept of time dilation by employing the techniques of virtual labs, so the respective lab becomes user-friendly.
- To experience a feeling of the physical lab in the theory classroom.

Methodology

Keeping in mind the complexity of understanding the time dilation effect in the Special Theory of Relativity course, we are scheming this lab. Many physics theories could not be understood by performing experiments in the laboratory due to either its cost on the higher side or experimentally can't be performed. It is very tedious to teach the concepts of physics without any feasible lab. Nowadays, all the complexities become simple due to virtual labs. The prerequisite to perform any experiment in the laboratory is a lab manual. Thus, we are presenting here a lab manual better to understand time dilation through the virtual lab. In methodology, we present the very first part of any lab that is aimed. Without any aim, it's not possible to understand the concept of physics. This study also involves an approach of pre-and pro-test that consists of multiple-choice questions and complicated problems. The user gets maximum chances to make all silly mistakes that could not be possible in our respective physical labs. Once the users go through all the steps, they can observe the output values by applying input values. Proper analysis can be done by doing graphical analysis. If we think about the cognitive level, we say that users can experience all the learning steps such as knowledge, comprehension, calculation, evaluation, analysis, etc.

Manual Design

An experimental design is introduced in this work by including aim, theory, procedure, pre-test, simulator, graphical analysis, calculation, percentage analysis, result, post-test. Users will be assigned all the steps in a sequence. The proposed design of the manual supports users in a broad way for a better understanding of the topic. Furthermore, this structure allows users to create blunders, and hence users can have effective learning by using this design.

We have designed a virtual lab manual for the proposed time dilation lab. The look of the same and its content is being discussed step by step.

Aim

The very first page of the manual contains multiple tabs on the left side of the page. During experiment, these tabs should be followed step by step. For example, on clicking the first tab, the experiment's aim is displayed on the screen, as shown in Figure 2.

Theory

The second tab is for the theory of the experiment where the underlying principle has been discussed (Figure 3).

Table1: Comparative understanding of time dilation using theory and virtual lab

Physics	*Topic (Time Dilation)*	*Availability in the text book*	*Effectiveness*	*Cognitive level*
Theory	Concept that is practically not possible in physical lab	Mathematical method of finding a relation of time dilation	Less effective	Knowledge, Comprehend, Evaluate
Virtual Lab	Can design	Can employ in a design by using computational methods(animation)	Most effective	Knowledge, Comprehension, Evaluate, Analyse, Innovate

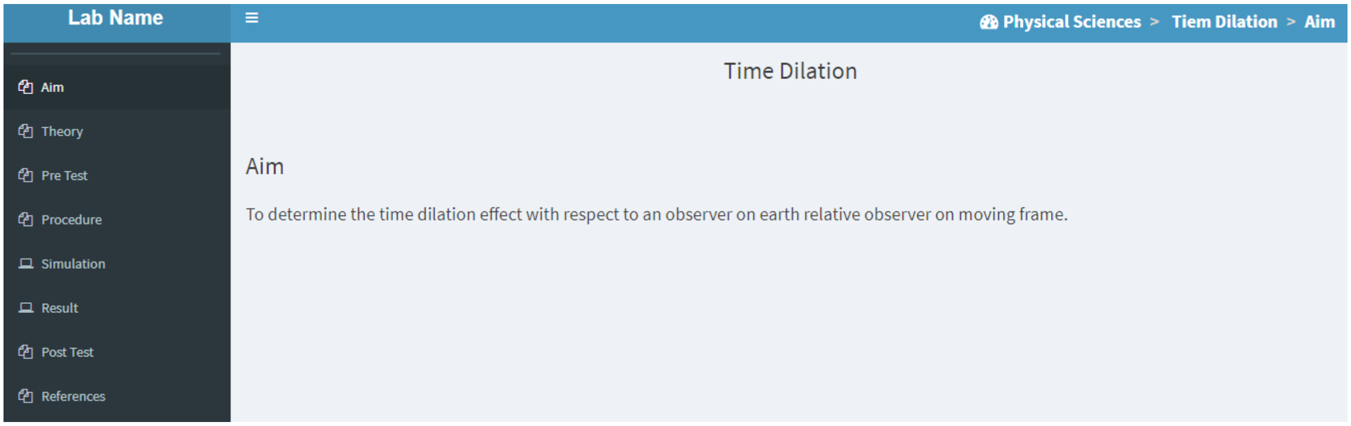

Figure 2: Aim of the experiment (Time Dilation)

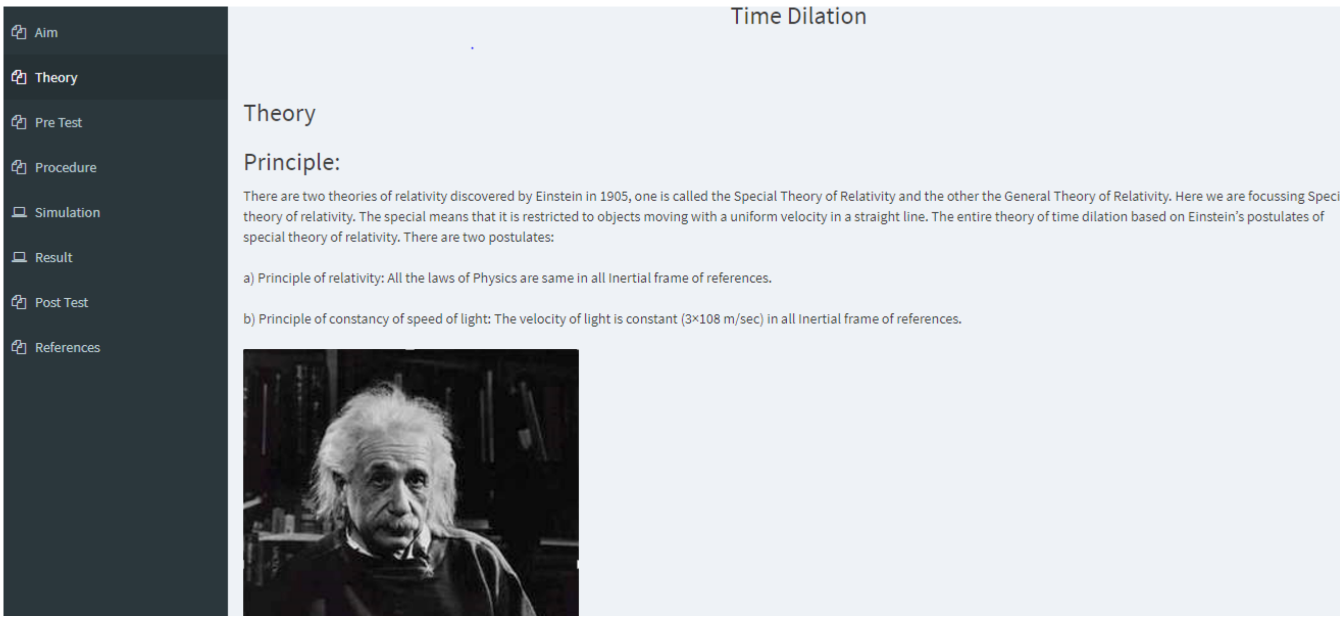

Figure 3: Theory/Principle of the experiment (Time Dilation)

Pre-test

The third tab is for Pre Test. Again, we can design a set of questions where the valuation of **pre**-existing subject knowledge could be done. Few Sample Questions in Pre Test are shown in Figure 4.

Procedure

Here, we present a systematic procedure to follow up the experiment instructions (Figure 5). There is a significant complexity to design procedure part of any particular concept of physics which is physically not possible in our respective labs. As in this situation, we structure the procedure by following the theoretical concepts of physics. Here mathematical tools always support a lot in designing the procedure of any experiment. Undoubtedly, it creates a pavement for the user for their better performance in the particular experiment.

Simulation

The simulation virtualizes the Time dilation effect. Thus, the user can view the effect of velocity variation on observed time. Screenshot of Simulation for object speed v = (0 to1) c m/s has been shown in Figure. 6.

Result

This tab gives the information concerning the result obtained in the experiment (Figure 7).

Post- Test

On clicking this tab, a set of questions appears on the screen (fig.8). This part is crucial as here the user can assess or evaluate his/her learning.

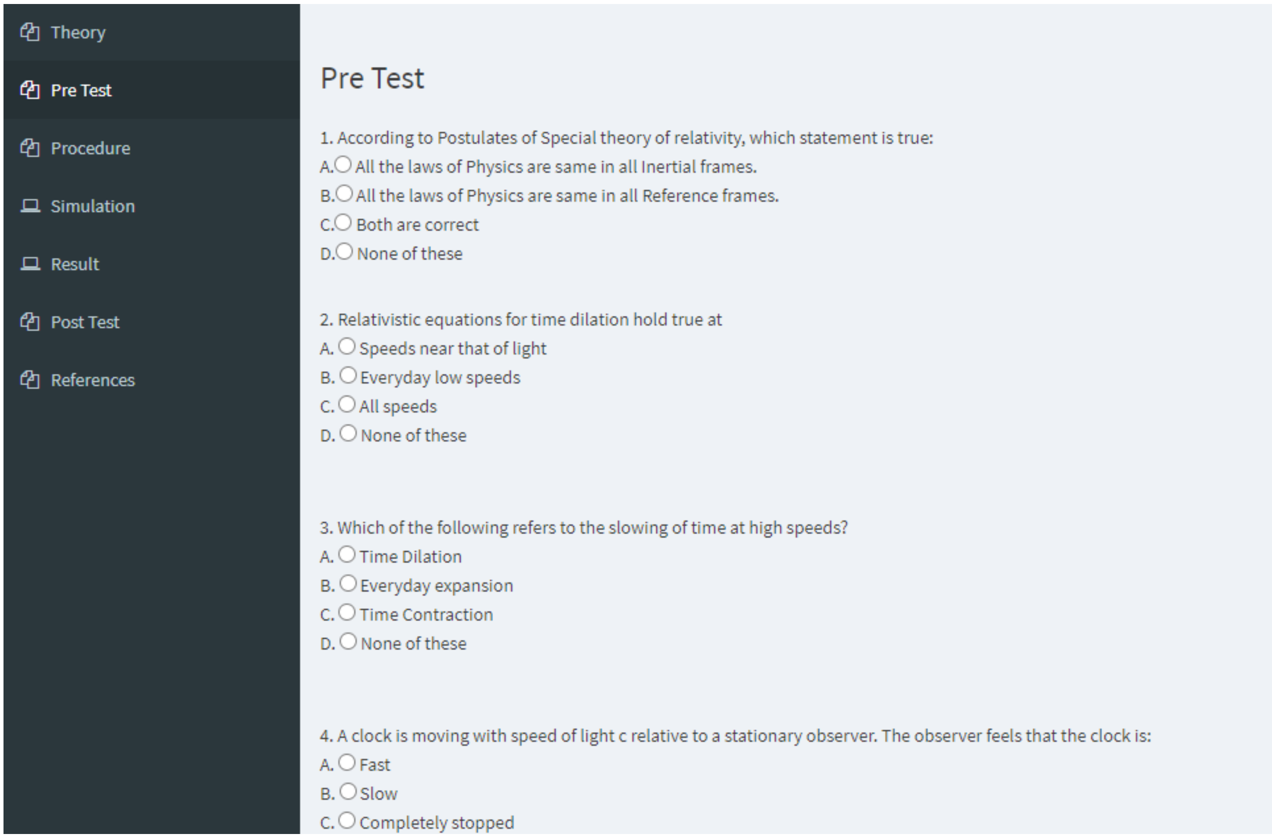

Figure 4: Sample questions in pre-test

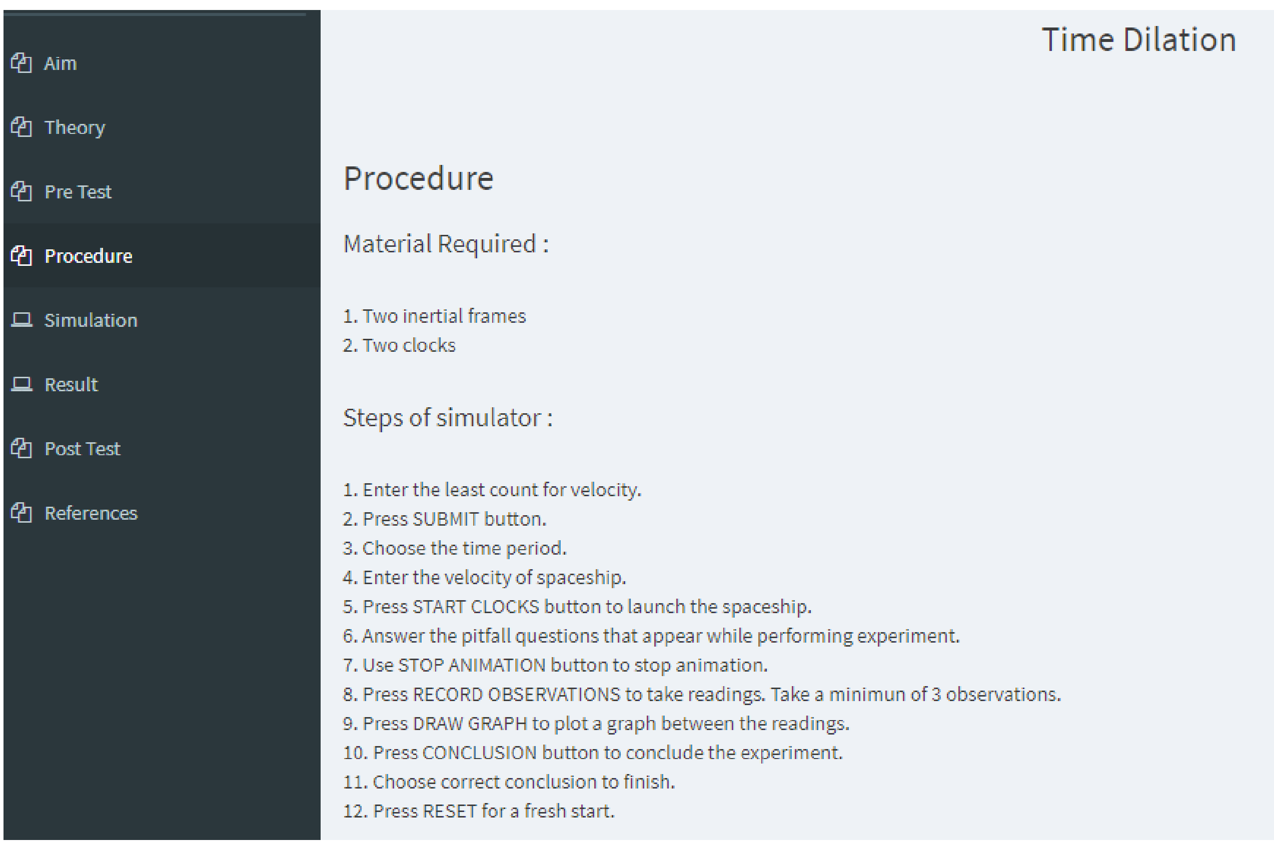

Figure 5: Steps of procedure

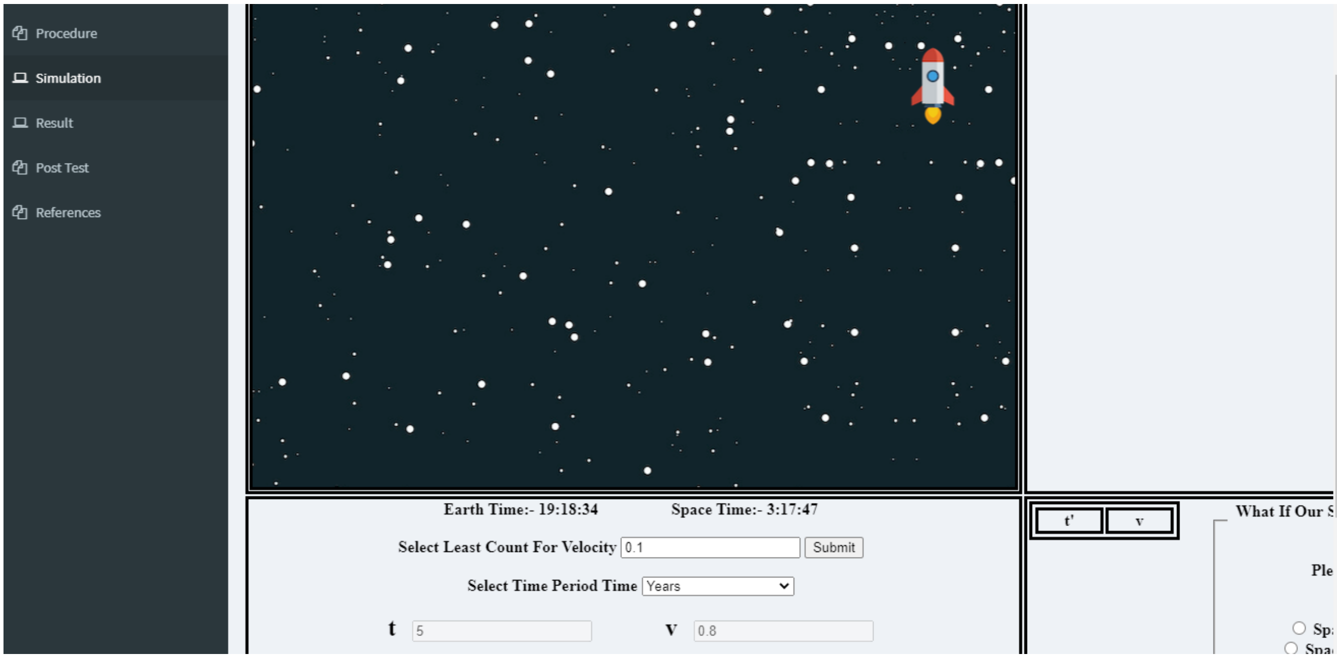

Figure 6: Simulation for v = (0 to 1) c m/s

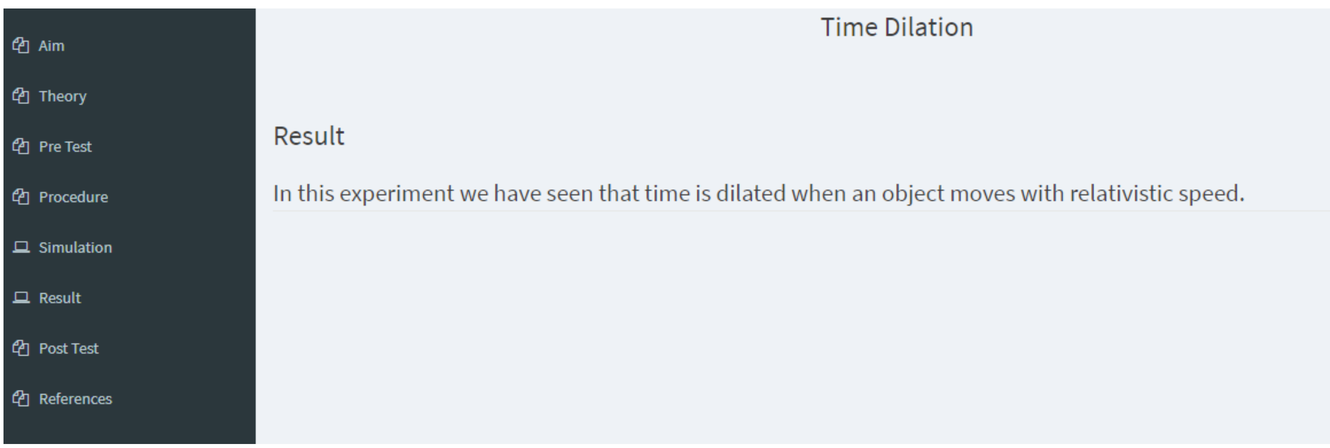

Figure 7: Result of the experiment (Time dilation)

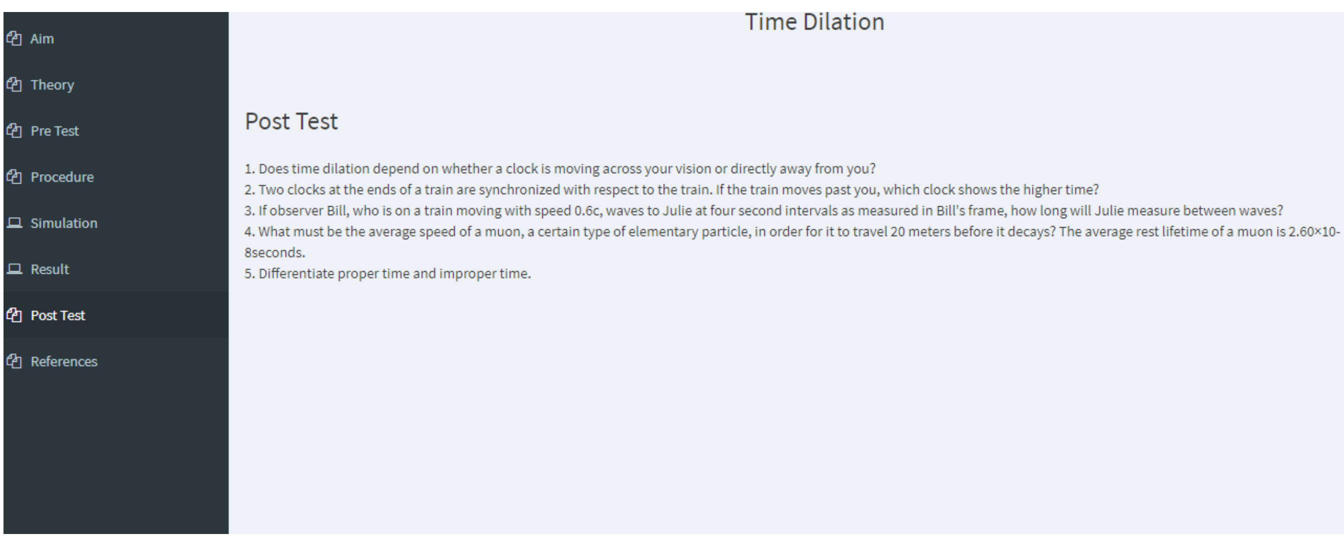

Figure 8: Sample questions in post-test

Table2: Comparative analysis of improper time measured in the virtual lab with the theoretical formula

S.NO.	*Velocity of the particle*	$\triangle t'_{VLab}$ *(Time measured using virtual lab)*	$\triangle t'_{formula}$	$\triangle t_0$	$\frac{\triangle t'_{VLab}}{\triangle t_0}$	$\frac{\triangle t'_{formula}}{\triangle t_0}$
1.	0.138	0.869	0.869	0.861	1.009	1.009
2.	0.266	1.726	1.725	1.663	1.038	1.037
3.	0.290	1.894	1.895	1.813	1.045	1.045
4	0.308	2.024	2.024	1.926	1.051	1.051
5	0.333	2.208	2.208	2.082	1.061	1.061
6	0.349	2.327	2.327	2.181	1.067	1.067
7	0.368	2.474	2.474	2.300	1.076	1.076
8	0.383	2.590	2.590	2.393	1.082	1.082
9	0.400	2.727	2.727	2.499	1.091	1.091

Results And Discussion

In this section, we presented the calculation. It seems that $\triangle t'_{VLab}$ as measured here and compare with $\triangle t'_{formula}$. There is a borderline difference between them. Here we are calculating $\triangle t'_{VLab}$ in terms of $\triangle t_0$ and we observe that variation can be seen in $\triangle t'_{VLab}$ as measured with formula $\triangle t'_{formula}$ (Table 2).

In the above calculations, we have compared the time interval values as measured in our simulator with a theoretical formula. We find that there is a marginal difference between experimental and theoretical values. The investigation shows that the Virtual lab values and the values obtained using the time dilation formula are in good agreement. Hence, the virtual lab of time dilation effect gives a complete environment to learn the concept of time dilation.

Conclusions

The existing literature shows that the concept of virtual labs positively influences the users. The current study states that teaching physics via interactive simulations imposes a positive impact on users' academic achievement. It says that virtual laboratories make learning physics concepts less complicated and effectively change the mood of users that negative insights of the theory course. Finally, we must say that virtual laboratories act as a bridge to understand the connection between theory courses and real-life events. It is believed that appropriate teaching methods and approaches should be used to pass on theoretical information.

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