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Blended Approach to Physics Problem-Solving Using Conventional and Virtual Labs: A Survey of Student's Perception

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ABSTRACT

Physics education entails rigorous problem-solving. But physics is full of abstraction and mathematical representations, which are hard to visualize. Hence, understanding the problems requires constant lab activities essential to physics problem-solving. But due to limited equipment and limited periods of usage in conventional labs, virtual labs are an alternative with their own set of limitations. So, a blend of the two virtual and conventional labs is a better option for problem-solving. A mixed-method approach was adopted to know the perception of higher secondary students towards this blended approach. For this, 150 CBSE board higher secondary students of science stream selected using convenient sampling from Lucknow were surveyed using a Likert-type perception scale comprising 15 items followed by an unstructured interview to know the preferred mode for physics problem-solving. The data so obtained were expressed in percentages. The study revealed that most students agreed with the overall perceived benefits of using conventional and virtual labs separately. But due to the inherent problems of these labs separately, students perceived the benefits offered by the blend of conventional and virtual labs in physics problem-solving more than using them separately. A blend of conventional and virtual labs should be used more often.

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INTRODUCTION

Problem-solving is an indispensable, inevitable, and inseparable part of science education (Ceberio et al., 2016; Ibrahim & Rebello, 2012). It is central to physics education also as physics is one of the main components of science education (Adams & Wieman, 2015; Docktor & Mestre, 2014; Docktor et al., 2010). It is a mechanism incorporated into learning physics to judge whether the concept has been learned (Docktor et al., 2016; Ceberio et al., 2016). A lot many versions of the definition of problem-solving exist. Some defined it as a form of discovery learning that acts as a bridge between a learner's prior knowledge and the solution of a problem (Ausubel, 1971). Some others viewed it as a cognitive process directed towards achieving a goal when there is no obvious solution to the problem (Meyer, 1992). It instills among the learners critical thinking, which is essential for decision-making skills (Ritchie & Thompson, 1988).

But, problem-solving in physics is a Herculean task as it involves abstract concepts that are hard to realize (Çildir, 2005). So, it requires constant experimentation to enable the visualization of concepts, thereby reducing the abstractness (Ceberio et al., 2016). Hence, when conventional lab experiences support these, problem-solving becomes easy. These labs not only help students to understand concepts but also enable them to define and explain the laws and theories through hands-on activities (Bajpai, 2013). But these conventional labs are sometimes hard to access and lack sufficient physical equipment (Yang & Heh, 2007) that are either very costly or require a lot of maintenance, thus, rendering lab activities unviable and costly affair.

So, there arises a need to look for alternatives, and the virtual lab is one such alternative. These laboratories have striking features that make them unique, like being safe to use without any constraints of time involved (De-Jong et al., 2013; Ceberio et al., 2016). Their design is such that they provide sufficient problem-solving activities to the students that may vary to a degree (Yuliati et al., 2018). Apart from these, students also have the flexibility to work either alone or in small groups towards completing lab activities and receive immediate feedback from the computer simulations (Darrah et al., 2014).

Hence, virtual labs play an indomitable role in problem-solving. But these labs also have certain limitations, such as less face-to-face interaction (Asal & Blake, 2006) and less recognition by accrediting agencies (Pyatt & Sims, 2007; Darrah et al., 2014). So, there is a need to implement a combination of these two, conventional as well as virtual labs, to solve the problems in physics. These invigorations of the features of both complement each other, thus making the combination of the two an invincible one. This combination that takes into account both online activities and face-to-face learning is called the blended approach to learning (Allen et al., 2007). So, students learn face-to-face in the classroom and concomitantly online outside the classroom. Therefore, in the present study, students of higher secondary stage study the physics problems content in the conventional labs as well as in virtual labs. Though the blended approach to learning has been very effective in increasing the performance outcome, motivation, and science communication skills in Physics courses (Rahmawatiet al., 2017), their usefulness in physics problem-solving is yet to be established. Even more specifically, the role of the blended approach in problem-solving through experimentation in conventional labs and virtual labs and the perception of higher secondary stage students about this is yet to be explored that is dealt with in this study.

Problem-solving skill is a higher-order and complex cognitive process (Docktor & Mestre, 2014; Yuliati et al., 2018) that is attained by a person when he understands the concepts well. Consequently, students find it hard to derive the meaning of the problem and hence cannot link it to their knowledge structure for that particular content area. Therefore, this was identified to be the basic reason by many researchers (Nakhleh, 1993). In physics education, it is concerned with abstract symbols rather than the physical meaning of the concepts. Due to the abstract nature of concepts in physics, it is difficult to realize the problems (Jian-Hua & Hong, 2012). Hence, these abstract concepts must be related to more concrete descriptions for students to understand the symbolic representations (Rosengrant et al., 2009; Yuliati et al., 2018).

So, problem-solving, when accompanied by lab activities, improve problem-solving skills (Hofstein, 2004) and is vital to physics teaching and learning. Conventional labs provide hands-on activities that give students procedural skills and develop among them an inquiry skill with which they explore the world around them. In addition, these labs also develop a positive attitude (Yeşilyurt et al., 2005) and a scientific perspective (Orbay et al., 2003). But it has its own set of disadvantages. They are hard to maintain and are a costly affair. Further, inadequate equipment prevents desired level of learning among the learners (Ayas et al., 2002), and limitations on hours of usage (Demir et al., 2011).

So, virtual labs are a fruitful endeavor that technological advances have offered. Physical labs are not sufficient to fulfill the various needs of diverse learners, so virtual labs emerged as an alternative. These labs are platforms that contain simulated experiments that are remotely triggered, and students learn the scientific concepts that govern the experiments through visualization and practice (Jones, 2018). They mock conventional physical labs, and they overcome many of the obstacles faced by students, such as safety, flexibility in conducting experiments and affordability, and no constraints in conducting experiments (Tüysüz, 2010). These labs positively affect students' lab experiences (Asikoy & Isek, 2017). They also help to visualize the concepts and allow one to answer the questions (Shih et al., 2016).

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Virtual labs are found to be effective in problem-solving of the students as they cater to different learning styles of students (Gunawan et al., 2017). They also found these labs to be more effective in problem-solving than conventional labs and enhance problem-solving ability, thereby making them far better planners and motivated to implement problem-solving more frequently. At the same time, the problem-solving ability of students is greatly enhanced by feedback in online learning activities reported by Demiraslan-Çevik et al. (2015). Besides this, students' literacy skills, such as those in designing graphs and predictions, are improved by experiments using computer programs (Subali et al., 2017). Though these labs have some noteworthy benefits yet have their own set of limitations such as idealized data, lack of collaboration, and the absence of interaction with real equipment (Hofstein & Lunetta, 1982; Nedic et al., 2003), less face-to-face interaction (Asal & Blake, 2006), less approved by accrediting agencies (Pyatt & Sims, 2007; Darrah et al., 2014).

So, it is advantageous to use a blend of conventional and virtual labs in problem-solving. This allows one to overcome the limitations of both by complementing each other. Learning with virtual labs has the advantage of making the invisible appear and also providing multiple representations of the concepts that are abstract (Ceberio et al., 2016). This paper is dedicated to this problem to know the perception of higher secondary students towards this approach.

The perception of higher secondary students matters the most as it is an important stage in the Indian education system which acts as a bridge between school and university education (National Council of Educational Research and Training, n.d). At this stage, students streamline themselves towards their careers. Hence, the perception of the students plays a critical role in problem-solving. In this regard, Koç (2015) reported a significant relationship between primary school students' perceptions of problem-solving skills and their learning process need for help. Not only this, female students see themselves all the more emphatically as far as problem-solving skills than their male counterparts.

So, from the literature review, it is concluded that though abundant literature exists on problem-solving that has focused its attention on it as a standalone problem, it is either none or very little in the context of conventional and virtual labs. The investigator also found a dearth of studies using the blended approach of conventional and virtual labs on physics problem-solving. So, this is a pertinent problem to know the perception of students about such an approach to problem-solving. At the same time, no such study was found to be conducted in India, particularly in Lucknow. Apart from this, problem-solving is an inseparable part of physics education, so it should be dealt with serious thought as the technological advancement of any nation depends on how its citizens make use of their learning in solving problems of day-to-day life. Therefore, the objections of this research are:

1. To find the perceptions of higher secondary students towards problem-solving in physics using a conventional lab.
2. To find the perceptions of higher secondary students towards problem-solving in physics using virtual labs.
3. To find the perceptions of higher secondary students towards problem-solving in physics by using a blend of conventional and virtual labs.
4. To find the preferred mode of physics problem-solving among conventional labs, virtual labs, and blended approaches.

RESEARCH METHOD

The population for this descriptive research comprised of higher secondary students of Lucknow city. Out of this, a sample of 150 class XI science stream students of Lucknow was selected using convenient sampling studying in CBSE boards that included both boys and girls. Only students studying in the higher secondary stage were included in the study. They were then surveyed for data collection using a questionnaire of Likert-type. An unstructured interview was also conducted to know the preferred mode of physics problem-solving by the students. The data obtained from the survey were analyzed using percentages and frequency counts. They were then presented in the form of tables and graphs, and interpreted.

The study is divided into four sections. The first section dealt with perception towards problem-solving in conventional labs, while the second section was to know the perception of higher secondary students towards the use of virtual labs for problem-solving in physics. The third section revealed the perception of higher secondary students towards the use of a blend of conventional and virtual labs in problems-solving in physics. The fourth section represents the data resulting from the interview that was intended to know students' preferred choices for physics problem-solving among conventional labs, virtual labs, and blended approaches.

The tool used for data collection

A 15-item perception scale developed by the research scholar was used for data collection. The scale items were Likert-type, ranging from strongly disagree to strongly agree. The scale was developed on three dimensions, namely,

- Perception of higher secondary students towards the use of conventional labs for problem-solving in physics
- Perception of higher secondary students towards the use of virtual labs for problem-solving in physics
- Perception of higher secondary students towards the use of a blend of conventional and virtual labs in problems-solving in physics

It had 13 positives and two negative items. The positive items were scored 5 for strongly agree and 1 for strongly disagree, while the negative items were scored 5 for strongly disagree and 1 for strongly agree.

An unstructured interview was also conducted to know the preferred mode for physics problem-solving among conventional labs, virtual labs, and blended approaches.

RESULTS AND DISCUSSION

The data obtained from the survey were tabulated in three tables and were interpreted.

Table 1. Perception towards physics problem-solving in conventional labs

No.	Item	Agree (percentage)	Disagree (percentage)	Neither (percentage)
1	The lab activities are quite engaging	65.3	28	6.7
2	They provide hands-on activities	80	6	14
3	They develop decision-making skills	65.3	15.4	19.3
4	They develop planning skills	73.3	12	14.7

As much as 65.3% of students agreed with the fact that lab activities keep students engaged, while 28% expressed disagreement with it. Besides this, 80% of students were found to be supportive of the fact that conventional labs provide hands-on activities. However, hardly 6% of students felt otherwise. Additionally, 65.3% of students agreed that traditional labs developed decision-making skills when others disagreed with the fact, and they accounted for 15.4%. Also, 73.3% of students supported the fact that conventional labs develop planning skills, whereas 12% did not support this (Table 1).

Table 2. Perception towards physics problem-solving in virtual labs

No.	Items	Agree (percentage)	Disagree (percentage)	Neutral (percentage)
1	It reduces abstraction in concepts	69.4	18.7	12
2	It does not increase the	36	56.7	7.3

	visualization of problems in physics			
3	It makes experimentation less feasible	43.3	50	6.7
4	It is more economical	63.3	18.6	18
5	It encourages experimentation	70.6	17.4	12

Though, 69.4% of students supported the fact that virtual labs reduce abstraction in the concepts, while 18.7% disagreed with it. When speaking of visualization of the concepts, 56.7% of students expressed disagreement that virtual labs do not increase visualization of the complex phenomenon, and only 36% of students agreed with it. Furthermore, 43.3% of students agreed that virtual labs make experimentation less feasible, but half of the students disagreed with this. Meanwhile, 63.3% of students perceived virtual labs to be more economical, but 18.6% opposed them. At the same time, 70.6% of students felt that virtual labs encourage experimentation, while 17.4% discarded this view (Table 2).

Table 3. Perception of students towards physics problem-solving using a blend of conventional and virtual labs

No.	Item	Agree (percentage)	Disagree (percentage)	Neutral (percentage)
1	The blend boosts confidence for problem-solving in physics	66.7	16.7	16.7
2	The blend encourages problem-solving in physics collaboratively	70.6	13.4	16
3	The blend develops higher-order thinking skills by problem-solving	73.4	12.7	14
4	The blend develops novel ideas for problem-solving in physics	64.7	24.0	11.3
5	The blend will change the outlook of students towards problem-solving in physics	71.3	13.4	15.3
6	The blend of conventional and virtual labs is more successful in problem-solving than traditional.	74.7	12	13.3

Out of the total, 66.7% agreed to the fact that the blend of virtual labs and traditional labs will contribute to a boost in confidence for problem-solving in physics, whereas 16.7% disagreed with it. In addition to this, 70.6% of students accepted the view that a blend of virtual and traditional labs surely encourages students to solve problems in physics with their peers collaboratively. On the other hand, 13.4% of students expressed disagreement. Furthermore, 73.4% of students agreed with the fact that the blend of virtual and traditional labs contributes to the development of higher-order thinking skills, whereas 12.7% of students disagreed with it. Besides this, 64.7% accepted the point that the blend of virtual and traditional labs helps develop novel ideas for problem-solving in physics, while 24% were against it. Moreover, 71.3% of students supported that the combination of virtual and traditional labs will change the outlook of students toward problem-solving in physics, and a mere 13.4% of students did not accept this. Notably, 74.7% of students agreed to the fact that the blend of conventional and virtual labs will be more successful in problem-solving than just the traditional labs or virtual labs (Table 3).

An unstructured interview was also conducted to know the preferred mode of physics problem-solving among conventional, virtual, and a blend of these two among higher secondary students and the reason behind their preference. The results are as follows in figure 1:

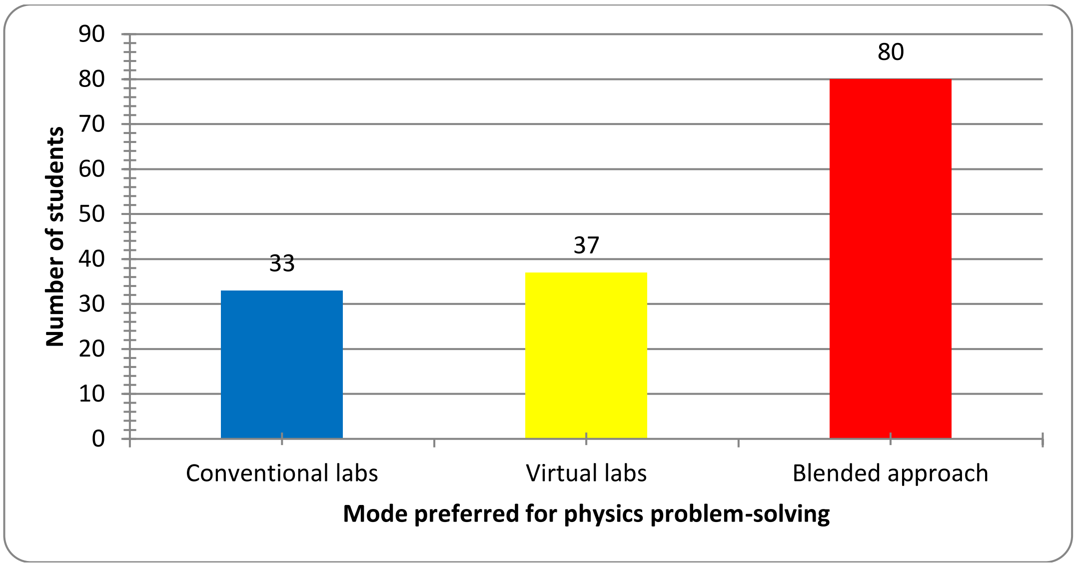

Figure 1. Students preferred mode for physics problem-solving

Eighty students preferred the blended approach for problem-solving and were highly preferred, while 37 students chose virtual labs and reasoned that they combine features of both conventional and virtual labs. However, only 33 students opted for conventional labs that were least preferred and opined that they gain real experiences that nothing can replace and be a substitute. But 37 students opted for virtual labs and concluded that they provide visualization of the abstract concepts that are hard to realize otherwise (Figure 1).

In the study, students perceived conventional lab activities to be engaging. They provide students an opportunity for hands-on activities as they get a chance to manipulate physical equipment. It also allows them to experience the subtleties of experimentation. Additionally, working with real equipment enhances the decision-making skills of the students (Okeke, 1995) while making them be better planners of the task. All these features of conventional labs help students to be better problem-solvers by enabling them to solve the problem by doing. But the limitations of space and time, the cost associated with the conventional labs, insufficiency of equipment, limited laboratory hours, and safety (Yang & Heh, 2007; Ullah et al., 2016; Rodríguez et al., 2012) make it hard to use them all the time. Therefore, it was the least preferred for problem-solving. So, virtual labs pose to be an alternative.

Most of the students perceived virtual labs to reduce abstractionism in concepts by providing mental models of the concepts, and also keep the students actively engaged in their learning processes (Finkelstein, 2005; Junglas, 2006). So are very useful in learning the concepts (Docktor et al., 2016; Ceberio et al., 2016). Additionally, it enhances the visualization by providing multiple representations of the phenomena supported by Ceberio et al., (2016). The virtual labs also make experimentation more feasible since no time bounds are imposed (De-Jong et al., 2014; Ceberio et al., 2016). These are accessible from anywhere and anytime without the worries of space and time. Also, these labs are far more economical (De-Jong et al., 2013) as only the initial cost accrued in developing the software. So they are less pricey than sophisticated instruments in conventional labs. But these have some noteworthy limitations too. Owing to the benefits, it was the second choice of the students.

Thus, the study revealed that students perceived a blended approach of experimentation using virtual and conventional labs to instill and boost confidence among the students as the students can either practice the experiments before entering the physical lab (Dyrberg et al., 2016; Kolil et al., 2020) or use them for practicing the experiments after working with physical equipment in conventional labs. Moreover, they can repeat them whenever they wish to (Herga et al., 2016). Hence it hones the problem-solving ability of the students while performing physical experiments (Avramiotis & Tsaparlis, 2013) and sharpens their critical thinking skills (Mashami & Gunawan, 2018). This deepens the knowledge that leads to a better understanding of physics problems. So, students are encouraged to problem-solving in physics collaboratively. Hence the students develop higher-order thinking skills and look for novel ideas for solving the physics problem. Most prominently, students also believed the approach to change the complete outlook toward problem-solving and predicted this combination to be more successful in physics problem-solving than either conventional or virtual labs alone. Hence, the blended approach is a novel approach that overcomes the limitations of both the conventional and virtual approaches giving students a chance to explore the problems from different angles and making it the highest in preference in comparison to either conventional labs or virtual labs. Thus, enabling the students to approach the problem in multiple ways. Thereby making physics problem-solving much more interesting, leading to meaningful learning. Therefore, it is of far more value in science education (De-Jong, Linn, and Zacharia, 2013). So, this was the first preference of the students for physics problem-solving.

CONCLUSION

The study revealed that students perceived virtual labs as effective tools for problem-solving in physics. But due to the limitations that the virtual labs pose, it is highly recommended to use a mix of the two, conventional and virtual labs, to benefit from the unique and striking features of both that complement each other. This study recommends that future researchers use the blended approach of conventional and virtual labs to solve physics problems using different approaches as much as possible for a clear understanding of the concepts and role of problem-solving in conceptual mastery. Although lab activities are crucial to physics education, it is not implemented rigorously into it. Henceforth, this study will motivate researchers to conduct research concerning the need and role of laboratories in various contexts, such as in developing higher-order thinking skills; and reasonable and logical understanding. So, it is imperative to integrate laboratory activities that are a blend of both conventional and technology-based labs. It can also be implemented in different other scientific areas.

But which option, the conventional or virtual lab, should be introduced when a question is to be explored further? It is also recommended that virtual labs should be designed carefully. Due care should be given to the lesson plans and unit plans keeping in mind the blended approach of virtual and conventional labs.

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