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RESEARCH ARTICLE

A SYSTEMATIC REVIEW ON RELEVANCE OF SIMULATED VIRTUAL LABS IN PHYSICS PROBLEM-SOLVING

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Abstract

Physics is the backbone of progress in science and technology. But it comprises complex problems that are an act of meta-cognition. Students find physics problems hard to solve due to abstraction, the inability to interlink theory to problems. But technologies like virtual labs offer several benefits such as safety, flexibility, affordability, and no barriers to space and time. Virtual labs enable visualization of the concepts. So they have the potential to play an important role in physics problem-solving. Therefore, this paper attempts to review secondary data on the relevance of simulated virtual labs in physics problem-solving and the various features that make it a preferred choice for it by excluding review and meta-analysis studies.

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Introduction:-

The 21st-century demands men who are adept problem-solvers and problem-solving should be an integral part of the teaching-learning process of any subject. In this regard, Martinez (1998) firmly opined that in a constantly changing technological society as of today, the capacity to solve complex problems is a vital skill expected of today's citizens. It is especially important for sciences that are full of problems and whose basic nature is to develop man into a rational being with the requisite scientific literacy and necessary intellectual resources. Even more specifically, physics is one of the sciences that pose rich and engaging contexts for problem-solving. It is one of the objectives of physics instruction at all levels of education when learning concepts and principles (Hsu, Brew, Foster, and Harper, 2004; Redish, Scherr, and Tuminaro, 2006).

Despite this, some physics instructors have found their students lack the desired level of proficiency in problem-solving (Redish, et al., 2006; Reif, 1995; Van-Heuvelen, 1991). This may be attributed to a lack of content knowledge (Reddy and Panacharoensawad, 2017), lack of sufficient practical hours or lab activities, insufficient number of instruments in the labs, accessibility of lab. One of the most important reasons is the abstraction of concepts in physics among many of the reasons that make learning physics hard.

So, technological affordances can play a pivotal role in reducing this abstractionism in physics concepts. The virtual lab is one such affordance. A virtual lab is an imitation of a real conventional lab (Babateen, 2011). These labs are designed in such a way as to provide sufficient problem-solving activities to the students that vary to a degree. So this study is an attempt to review the literature to understand the preference of virtual labs in physics problem-solving.

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Background of the study

Problem-solving apart from being a higher-order thinking skill involves complex cognitive processes (Docktor and Mestre, 2014; Yuliati et al., 2018). Notably, the cognitive approach to problem-solving is associated with meta-cognition which is self-awareness of an individual's thought process (Ormrod, 2004). Subsequently, these meta-cognitive problem-solvers can successfully plan, monitor, and evaluate their problem-solving strategies. Such individuals implement meta-cognition strategies and evaluate solutions from diverse perspectives (Yuliati, Riantoni, and Mufti, 2018). Hence are successful in solving complex problems because they are adept evaluators of their assumptions and do not persevere in unproductive strategies. Usually, complex problem-solving requires complex skills. So one requires an organized conceptual understanding and relevant procedural knowledge. Likewise, various factors contribute to the successful problem-solving ability of a student such as cognitive ability, problem-solving approach (Yuliati, Riantoni, and Mufti, 2018), characteristics, and reasoning (Docktor et al., 2016), the capacity to interlink different representations concerning the concepts (Ceberio, Almudi, and Franco, 2016), and experience (Hull, Kuo, Gupta, and Elby, 2013; Docktor and Mestre, 2014; Docktor et al., 2016; Yuliati, Riantoni, and Mufti, 2018).

Problem-solving is an inherent feature of physics education (Adams and Wieman, 2015; Docktor and Mestre, 2014; Docktor, Strand, Mestre, and Ross, 2010). Whilst being a mechanism in learning physics, it's an evaluation criterion for the attainment of the concepts (Docktor et al., 2016; Ceberio et al., 2016). Another reason for linking problem-solving in physics education is abstract symbols that do not consider the physical meaning of the concepts. So problem-solving relates abstract concepts to more concrete descriptions (Rosengrant, Heuvelen, and Etkina, 2009; Yuliati, Riantoni, and Mufti, 2018). But the visualization is impossible without the aid of technology. Virtual labs are such computer technologies that are defined as a simulated environment that enables learners to interact with virtual apparatus as well as materials to conduct experiments on a computer. Shih, Singh, and Hoiem (2016) contemplated that virtual labs help to visualize the concepts and thus enable them to answer the questions. So, they are seen as popular alternatives to traditional laboratories due to many of the benefits. These include more manageable, safe to use, cost-efficient, clean, flexible, and rapid than physical experiments and no constraints in conducting experiments (Yeni and Yokhebed, 2015; De-Jong, Linn, and Zacharia, 2013). Incidentally, these have a positive effect on students' lab experiences (Asikoy, 2017). Likewise, several studies have evinced the positive learning effects of virtual environments that support learners not only to explore, test hypotheses but also to analyze data like scientists do (McElhaney, 2007; Sun, Lin, and Yu, 2008; Chen, 2010). Besides this, Subali, Rusdiana, Firman, Kaniawati, and Ellianawati (2016) supported the fact that experiments using computer programs help to improve student's literacy skills and in particular designing graphs and predicting. Additionally, their effectiveness in increased conceptual understanding is more pronounced as compared to traditional laboratories (Zacharia and Constantinou, 2008; Chen, 2010).

Apart from this, virtual labs have a perceptually constraining feature that not only provides cognitive support such as embedded software tools but also increases the accessibility of science. It also lets the learner focus only on the variable of consideration rather than the numerous variables needed during the hands-on inquiry leading to a reduction in the cognitive load (Toth, Ludvico, and Morrow, 2014) during knowledge construction. Hence, are proved to be more effective in problem-solving (Flowers, Moore, and Flowers, 2011). It is because their design is in sync with the unique learning styles of individual students (Gunawan, Harjono, Sahidu, and Herayanti, 2017; Gunawan et al., 2019).

However, a combination of real and simulated lab tools supported by real data recorded in the computer-aided form leads to a sound understanding of physical systems as cited by Hansson and Bug-Amy (1995) and Darrah, Humbert, Finstein, Simon, and Hopkins (2014). Such technology can also be used as a thinking tool to make learning a meaningful act (Darrah et al., 2014). According to Thornton (2008) and Darrah et al. (2014), computer simulations that are supportive of real-time data logging help in conceptual learning. These when accompanied by an activity-based and research-based environment that supports peer learning are the most suitable environment for student learning in physics.

Objectives of the study:-

1. To study the relevance of virtual lab in physics problem-solving.
2. To determine various features of the virtual lab that make it a preferred choice for physics problem-solving.

Methodology:-

In this study, the data has been searched from various databases such as Eric, ResearchGate, Academia, Science Direct, ProQuest, Elsevier, and Taylor and Francis. Here 40 research papers were reviewed but twenty-five papers were found relevant for the study. The keywords fed to search the literature were “problem-solving”, “problem-solving skills”, “problem-solving in physics”, “problem-solving using virtual labs”, and “problem-solving in physics using virtual labs”. Review papers and meta-analyses have been excluded from the study. Papers published in journals, thesis, dissertations have been reviewed for the paper. On reviewing the literature, the following themes emerged: relevance of virtual labs in physics problem-solving, striking features of the virtual lab that make these labs viable for problem-solving. Below Fig. 1 depicts the way literature was searched and sorted.

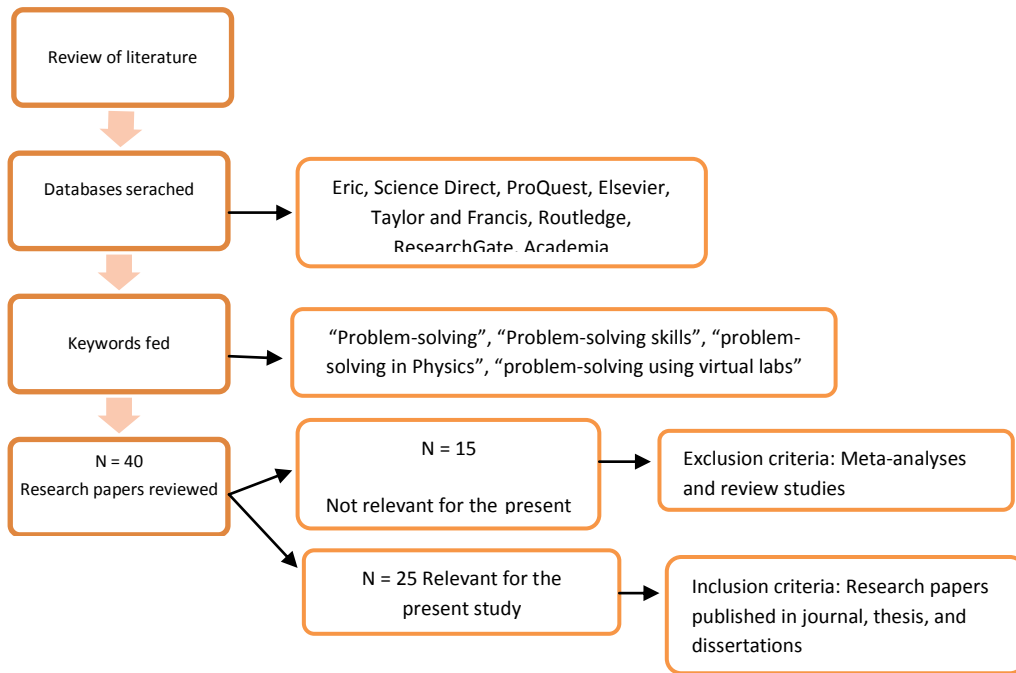


Fig. 1:- Flowchart to show literature search and sorting process.

Results and Discussion:-

Relevance of virtual labs in physics problem-solving

Most of the researchers contemplated that virtual labs are of great help in problem-solving as they are capable of making abstract concepts visible by providing multiple representations of the concepts, hence more capable of providing multiple solutions to approach a problem. They also enhance the conceptualization of concepts (Triona and Klahr, 2003, Klahr, Triona, and Williams, 2007), keep the students focused on the problem at hand, and hence reduce the cognitive load (Mayer and Moreno, 1998; Mayer, 1992). Additionally, they cater to various learning styles of the students and are helpful in better planning and implementing problem-solving. In conjunction with these, the labs can also be used as a thinking tool and support peer learning. All these unique features make virtual labs a preference for problem-solving in physics over conventional physics labs. Therefore, some researchers suggest the replacement of physical labs with virtual labs.

Striking Features of virtual labs that make them viable for physics problem-solving

In making virtual labs a preferable choice for problem-solving, it is the design of virtual labs that have played a significant role. These labs can be used in any space and time (Triona and Klahr, 2003) and this makes them be used from far-off remote areas where lab facilities are hard to access. Besides, these labs are flexible to use (Zacharia and Constantinou, 2008), students need not wait for the practical periods to use these labs and can use them after school hours as and when needed. Additionally, these labs are hazard-free (Tüysüz, 2010) because these include only simulations so there is no chance of getting an electric shock or cutting, or exposure to any kind of rays. Most importantly, these labs are over the internet so are affordable.

Conclusion and Implications of the study:

Problem-solving is vital to physics teaching. But students find it difficult due to many reasons as cited in this review. They lack clear visualization of the problem or they find it difficult to link the new information with the previous one. So, many investigators opined the use of virtual labs for this, given its unique features. So, this study may motivate future researchers to research the use of a combination of virtual labs and traditional labs for problem-solving.

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