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A Comprehensive Analysis of the Importance of Simulated Virtual Laboratories in Physics Problem-Solving

G. B Raman[1], Puneet Singh[2], Rajesh Gadhwal[3]

Associate Professor[1], Students[2, 3]

Department of Physics

Gyan Ganga College of Technology Jabalpur

Corresponding Author's Email: *puneetsingh12@gmail.com*

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.

Keywords*: - Relevance, Systematic Review, Problem-Solving, Simulated, Virtual Lab, Physics*

INTRODUCTION

The twenty-first century requires individuals who are skilled problem solvers, and problem solving should be an intrinsic element of every subject's teaching-learning process. Martinez (1998) firmly believes that in today's continually changing technological culture, the ability to tackle complicated issues is a fundamental talent needed of today's population. It is especially vital for disciplines that are riddled with issues and whose primary goal is to grow man into a rational creature equipped with the appropriate scientific literacy and intellectual resources. Physics, in

particular, is one of the disciplines that provides rich and intriguing environments for problem solving. When studying concepts and principles, it is one of the goals of physics training at all levels of education (Hsu, Brewe, Foster, and Harper, 2004; Redish, Scherr, and Tuminaro, 2006).

Despite this, several physics professors have discovered that their pupils lack the requisite level of problem-solving skill (Redish, et al., 2006; Reif, 1995; Van-Heuvelen, 1991). This might be due to a lack of subject understanding (Reddy and Panacharoensawad, 2017), a lack of appropriate practical hours or lab activities, an insufficient number of instruments in the laboratories, or lab accessibility. Among the numerous factors that contribute to the difficulty of learning physics is the abstraction of notions.

As a result, technological affordances can be critical in minimising abstractionism in physics ideas. One such opportunity is the virtual lab. A virtual lab is a replica of a traditional lab (Babateen, 2011). These laboratories are constructed in such a manner that students may engage in a variety of problem-solving tasks. As a result, the purpose of this study is to conduct a literature review in order to better understand the preference for virtual laboratories in physics problem solving.

Background of the study

Aside from being a higher-order thinking talent, problem-solving entails complicated cognitive processes (Docktor and Mestre, 2014; Yuliati et al., 2018). Notably, the cognitive approach to problem-solving is linked to meta-cognition, or self-awareness of one's own mental process (Ormrod, 2004). As a result, these meta-cognitive problem-solvers can plan, monitor, and assess their problem-solving tactics with success. These people use metacognition tactics and assess solutions from several viewpoints (Yuliati, Riantoni, and Mufti, 2018). As a result, they are successful in addressing complicated problems because they are skilled judges of their assumptions and do not persist in ineffective techniques. Typically, complicated problem-solving necessitates complex talents. As a result, an ordered conceptual understanding and corresponding procedural expertise are required. Similarly, cognitive ability, problem-solving approach (Yuliati, Riantoni, and Mufti, 2018), characteristics and reasoning (Docktor et al., 2016), the ability to interlink different representations of concepts (Ceberio, Almudi, and Franco,

2016), and experience all contribute to a student's successful problem-solving ability (Hull, Kuo, Gupta, and Elby, 2013; Docktor and Mestre, 2014; Docktor et al., 2016; Yuliati, Riantoni, and Mufti, 2018).

Problem-solving is an essential component of physics education (Adams and Wieman, 2015; Docktor and Mestre, 2014; Docktor, Strand, Mestre, and Ross, 2010). While it is a process for learning physics, it is also an assessment criteria for concept acquisition (Docktor et al., 2016; Ceberio et al., 2016). Another argument for connecting problem-solving in physics education is the use of abstract symbols that do not take into account the physical meaning of ideas. As a result, problem-solving connects abstract notions to more specific explanations (Rosengrant, Heuvelen, and Etkina, 2009; Yuliati, Riantoni, and Mufti, 2018). However, without the assistance of technology, visualisation is impossible. Virtual laboratories are computer technologies that are characterised as a simulated environment that allows learners to engage with virtual apparatus and materials to conduct computer experiments. Shih, Singh, and Hoiem (2016) proposed that virtual laboratories assist students envision topics and hence answer problems. As a result of these advantages, they are considered as appealing alternatives to traditional laboratories. These advantages include being more controllable, safe to utilise, cost-effective, clean, versatile, and quick than physical investigations, as well as having no limits in performing experiments (Yeni and Yokhebed, 2015; De-Jong, Linn, and Zacharia, 2013). In addition, these have a good impact on students' laboratory experiences (Asikoy, 2017). Similarly, multiple studies have demonstrated the good learning impacts of virtual environments that enable learners not only to explore and test theories, but also to evaluate data in the manner of scientists (McElhaney, 2007; Sun, Lin, and Yu, 2008; Chen, 2010). Furthermore, Subali, Rusdiana, Firman, Kaniawati, and Ellianawati (2016) reinforced the idea that computer-assisted experiments might help students enhance their literacy abilities, particularly in graph creation and prediction. Furthermore, as compared to typical laboratories, their usefulness in increasing conceptual comprehension is more evident (Zacharia and Constantinou, 2008; Chen, 2010).

Aside from that, virtual labs have a perceptually restricting characteristic that not only offers cognitive assistance, such as embedded software tools, but also promotes the accessibility of science. It

also allows the learner to focus just on the variable under examination rather than the several variables required during the hands-on inquiry, resulting in a reduction in cognitive load (Toth, Ludvico, and Morrow, 2014) during knowledge production. As a result, they have been shown to be more successful at problem-solving (Flowers, Moore, and Flowers, 2011). It is because their design is in harmony with the varied learning styles of each pupils (Gunawan, Harjono, Sahidu, and Herayanti, 2017; Gunawan et al., 2019).

According to Hansson and Bug-Amy (1995) and Darrah, Humbert, Finstein, Simon, and Hopkins (1995), a mix of actual and simulated lab instruments backed by real data collected in computer-aided form leads to a solid knowledge of physical systems (2014). Such technology may also be utilised as a thinking tool to make learning more relevant (Darrah et al., 2014). According to Thornton (2008) and Darrah et al. (2014), computer simulations that offer real-time data logging aid in conceptual learning. These, when combined with an activity-based and research-based atmosphere that promotes peer learning, provide the best setting 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 makes it a preferred choice for physics problem-solving.

METHODOLOGY

Data for this study was retrieved from databases such as Eric, ResearchGate, Academia, Science Direct, ProQuest, Elsevier, and Taylor & Francis. In this case, 40 research publications were screened, but only twenty-five were judged to be relevant to the study. "problem-solving," "problem-solving skills," "problem-solving in physics," "problem-solving utilising virtual laboratories," and "problem-solving in physics using virtual labs" were the keywords used to search the literature. The research did not include review papers or meta-analyses. For the article, papers published in journals, theses, and dissertations were reviewed. Following a study of the literature, the following themes emerged: the importance of virtual laboratories in physics problem solving, and the distinguishing properties of virtual labs that make these labs feasible for problem solving. The method for searching and sorting literature is depicted in Fig. 1.

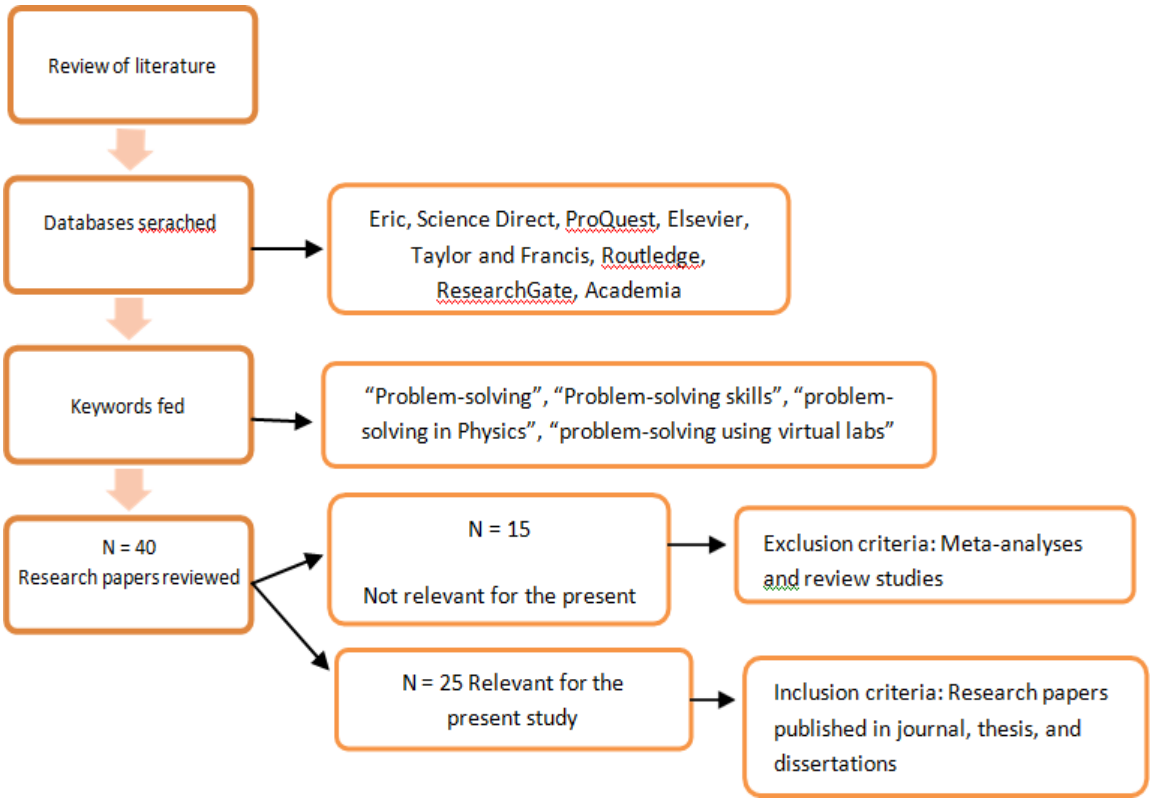

Fig. 1:- Flowchart to show literature search and sorting process

RESULTS AND DISCUSSION

Relevance of virtual labs in physics problem-solving

Most of the researchers agreed that virtual labs can help with problem solving because they can make abstract concepts accessible by giving different representations of the concepts, making them more capable of presenting multiple approaches to a problem. They also improve idea conceptualization (Triona and Klahr, 2003; Klahr, Triona, and Williams, 2007), keep pupils focused on the topic at hand, and so minimise cognitive load (Mayer and Moreno, 1998; Mayer, 1992). Furthermore, they accommodate to students' diverse learning styles and aid in better problem-solving planning and implementation. In addition, the laboratories may be utilised as a thinking tool and to enhance peer learning. All of these distinguishing characteristics make virtual laboratories preferable to traditional physics labs for problem-solving in physics. As a result, some researchers propose that physical laboratories be replaced by virtual labs.

Characteristics of virtual labs that make them suitable for physics problem-solving

The architecture of virtual labs has played a key influence in making them a

preferable alternative for problem-solving. These labs may be utilised in any location and time (Triona and Klahr, 2003), allowing them to be used in remote areas where lab facilities are difficult to reach. Furthermore, these laboratories are adaptable (Zacharia and Constantinou, 2008); students do not need to wait for practical sessions to use them and can use them outside school hours as needed. Furthermore, these labs are risk-free (Tüysüz, 2010) since they only feature simulations, therefore there is no risk of electric shock, cutting, or exposure to rays. Most significantly, because these laboratories are accessible over the internet, they are inexpensive.

CONCLUSION AND IMPLICATIONS OF THE STUDY:

Problem-solving is essential in physics education. However, pupils find it challenging for a variety of reasons, as outlined in this evaluation. They lack a clear image of the situation or find it difficult to connect new knowledge to past information. Given its distinct advantages, numerous scientists advocated the use of virtual labs for this purpose. As a result, this work may inspire future researchers to investigate the use of a hybrid of virtual and traditional labs for problem solving.

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