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A Comprehensive Review on PBL and Digital PBL in Engineering Education - Status, Challenges and Future Prospects

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Abstract: Problem-based learning (PBL) makes use of complex, real-world issues as the subject matter, and encourages students to develop problem-solving skills and learn concepts instead of just absorbing facts. The emergence of the concept of PBL in the digital learning context has received massive recognition and has thus, triggered debate among several scholars. Therefore as a prelude to analysis, the present study attempts to review the existing literature on PBL, particularly in the context of digital learning with respect to engineering education. It further attempts to discuss the ways for PBL implementation, its related challenges and future prospects, especially in the digital setting. The study adopted a systematic literature review wherein it selected relevant studies, articles and papers that broadly discussed the significance of the topics and evaluated information and data from the period starting from 2012 through 2021.

A comprehensive review of the literature revealed that since digital PBL includes diverse and multiple digital technology applications as part of traditional PBL it is more effective than the traditional form of learning and it is most widely used in engineering education as the aim of engineering education is to generate such students who are practically equipped with technical knowledge and considerably prepared with professional engineering skills. However, there exists a paucity of research on digital PBL which needs further analysis.

Keywords: engineering education, problem-based learning, digital PBL, e-learning, online PBL, PBL implementation

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1. Introduction

Over the last few years, governments, educational institutions and other stakeholders have made huge investments in engineering education and new insights have been acquired regarding the form of learning in different domains of engineering, and developments in new methods of educational research have been made and an increased number of instructors have become aware of the "evidence-based instructional practices" (Violante & Vezzetti, 2014). Engineering education mainly deals with making students become experts in solving "uncertain, complex, open-ended workplace problems." Therefore in recent times, problem and project-based learning (PBL) has been adopted in engineering education as a result of its projected effectiveness and benefits in the development of the "professional knowledge and transferable skills" of students thereby improving their learning outcomes (Richert et al., 2016). Although the implementation of PBL strategies in various settings and systems of education differ widely ranging between curriculum and course level, problem-oriented and project-oriented as well as single subject to multidisciplinary, the primary principle states that in the process of education students are self-motivated and emerge as owners of their education process, remain the same (Wahyudi, 2020). Several scholars developed a theoretical framework of the different types of PBL implementations and practices including "PBL for knowledge management, PBL through activities, project-led PBL, PBL for practical capability, PBL for design-based learning, PBL for critical understanding, PBL for multimodal reasoning, collaborative distributed PBL, and PBL for transformation and social reform." However, the authors stated that the current PBL practice that should be paid more attention to is the practice of PBL through digital platforms (Rice & Shannon, 2016).

The pedagogical strategies such as PBL which have pre-established learning methods are being increasingly adopted for digital use in alignment with the "Web 2.0" tools and technologies of the modern technologically advanced world. Problem-based learning is a student-oriented pedagogy that takes into account these technological advances; however, it also incorporates various other ideals of pedagogy that are relevant to the "web 2.0" education structure. Although PBL is mainly a multidimensional pedagogy that can be structured in multiple ways, some of the PBL aspects need to be organized more individualistically focusing on self-directed learning whereas a few others need to be organized more socially to promote collaborative learning among learners (Sada et al., 2016). Therefore, the employment of different environments and technologies have been done to assist the various PBL organizations. However, significant differences may exist in the different forms of PBL practices as well as the socio-technical solutions generated to help these (Ibragimov et al., 2016).

The most interesting aspect of the development of online PBL practices is that they facilitate various social constellations such as groups where learners engage together in finding a solution to a common problem, project, etc. The "Virtual Learning Environment" is considered to be the best strategy for offering instruction for PBL cycles as they provide increased opportunities and motivation for learners to engage with regard to their connection with "resources, peers and experts" (Mahgoub & Sundaravadivel, 2021). PBL in digital learning has a number of underlying principles in terms of developing learning motivation among students by making full use of the power of real-life situations, employment of the "global information network" by designing the learning environment in a relevant manner, encouraging educational development to learn "processes, heuristics and thinking skills," emphasizing the importance of "problem-solving and decision making," providing opportunities for applying knowledge in projects actively, and engaging in an extensive search of information (Qadir & Al-fuqaha, 2020). However, due to the significant variation in the PBL practices, it comes with multiple challenges which are not just specific to any technological field but are rather general for all levels of education. The PBL challenges are faced by students, teachers and institutions alike. At the individual level, the challenges are faced by students and teachers in their respective courses or projects of PBL; at the institutional level, the challenges are faced by the faculty members, departments as well as the institution as a whole (Li & Faghri, 2016). Therefore future developments in this field should primarily focus on developing support initiatives to improve the system of online PBL in the different fields of education, particularly engineering education. Apart from this, future work should also focus on enhancing the digital platforms with new tools and features and applying the framework of "PBL 2.0" in varying contexts of learning (Cruz et al., 2021).

1A. Objectives of the study

- To understand the ways of PBL implementation, monitoring and evaluation using digital platforms.
- To understand the challenges involved in the above-mentioned objective.
- To study and quote the future prospect of the same.

2. Literature Review

For the purpose of the present study, the extant literature has been selectively reviewed in conjunction with the objectives of the research framework. It helps in identifying the remaining gaps in the chosen area of research and also suggests directions for future research.

2A. Overview of Engineering Education

According to Graham (2018) at present, the productivity of the world has increased manifold and it has become a place where engineering with the help of technology has made an irrevocable impression on the lives of individuals as well as their identity. It has been observed by Hussein (2021) that engineering and scientific knowledge is constantly improving and this is primarily reflected in the increasing technological growth rate. Over time more functional and cheaper versions of the existing technologies are being introduced such as those in the field of "biotechnology, nanotechnology, information and communications technology, material science and photonics" which will bring about changes in engineering education that will continue up to the next five years and beyond (Jeon et al., 2014).

In recent times Engineering education has evolved drastically to enhance student learning as a result of the changes put forth by national and international organizations (Jollands & Parthasarathy, 2013). Among the various significant responses, the incorporation of "team-based, project-driven activities" has been the most prominent one (Khanna et al., 2020). However, the authors argued that many new improvements are required in alignment with the twenty-first-century world for the preparation of engineering students to meet new challenges (Gaivoronskii, Kutuzov & Minina, 2017). The development of professional expertise in engineering education is best supported by effective learning experiences (Christie & De Graaff, 2017). "Effective learning experiences refer to those that support the development of deep understanding organized around key concepts and general principles, the development of skills, both technical and professional, and the application of knowledge and skills to problems that are representative of those faced by practising engineers." (Yogeshwaran, Kaur & Maheshwari, 2019). According to Swart (2015), "the types of learning approaches that lead to a deep understanding of the concepts and principles of a domain are referred to as deep approaches to learning." Lynch et al. (2012) identified multiple strategies that could help in the promotion of "deep learning" such as those relating to knowledge, experience and ideas of the past, underlying principles and patterns, finding evidence and then making conclusions, and carefully assessing logics and arguments. Another form of deep learning approach identified by Palmer & Hall (2011) that was associated with engineering education included "application-oriented learning" where attention is mainly paid to those parts of the subject that are practically relevant. "Application-oriented" approaches include looking for a linkage between reality and the area under investigation, practical application of the learning and seeking to replace the reasoning of abstract lines with concrete evidence (Nino & Evans, 2015). Studies on engineering education and the characteristics of important learning experiences revealed that integrated diverse learning experiences and application of knowledge and skills to real-life situations were the most effective form of engineering learning (Akor et al., 2018). Few characteristics of "effective learning experiences" included students developing strategies for learning a particular domain and regulating their own learning process. Self-regulation helps in improving their skills in different areas of engineering and their performance in exams as well (Block et al., 2020). According to Chesler et al. (2015) learning practices such as perception of students towards the learning experience value, expectations of students regarding the creation and execution of a plan to achieve learning goals and tasks and perception of students towards the learning environment designed by the instructor to support student learning are likely to improve the experiences of engineering students. Coskun, Kayikci & Gencay (2019) also highlighted the importance of instructors' challenging students with tasks at a suitable level and also offering them adequate support to ensure the successful integration of their knowledge and skills to finish a given task.

In the context of engineering education,"the development of deep conceptual understanding in a domain is a necessary condition for the development of expertise" (Kuppuswamy & Mhakure, 2020). However most students fail to develop this understanding due to conventional instruction and therefore substantial improvements in the form of instruction of subjects like physics are required (Lantada & Maria, 2019). Conventional instructions mainly focus on solving traditional, textbook-type problems that do not include real-life situations. It appeared that teaching approaches involving "interactive engagement" led to significant improvements in the learning of subjects like physics which require conceptual understanding (Chowdhury, 2015). Furthermore, as students start conducting engineering analysis on a particular area as "thermodynamics" they often follow "algorithmic approaches" to problem-solving. For example, they might observe something as a "pump problem" or a "turbine problem" which mainly occurs out of the understanding of the features of surface problems rather than deep conceptual learning (Morales et al., 2015). Therefore effective learning would shift students' focus towards deeper understanding than a surface-level understanding of a subject matter (Chua, Yang & Leo, 2014). Therefore emphasizing learning activities develop opportunities for different kinds of learning experiences including "traditional problem-solving classes (tutorials), project-based learning, work placements, design tasks, laboratory work, etc" that are in conjunction with the features of effective learning experiences (Gadola & Chindamo, 2019).

2B. Problem-Based Learning (PBL)

According to Wood (2003), "problem-based learning (PBL) uses complex, real-world issues as the classroom's subject matter, encouraging students to develop problem-solving skills and learn concepts instead of just absorbing facts." It is considered a style of teaching that facilitates students to become the drivers of their own knowledge and learning. In a project involving problem-based learning, students have the liberty to pitch their ideas and plans to solve a particular problem. It allows students to work independently or in teams and engage in conceptualizing, designing, and launching their products of innovation near fellow students and instructors (Chen & Yang). Problem-based learning follows a "learner-centred approach" that helps in empowering students towards conducting research, integrating theory into practice and applying knowledge and skills towards the development of proper solutions to a government problem thereby achieving a personal experience of education. Being an "immersive educational model" problem-based learning works towards the promotion of students' self-learning, engages them to a great extent, develops transferable skills in them, enhances their ability to work in teams, encourages intrinsic rewards and so on (Habok & Nagy, 2016).

According to Savery (2015), the different methods used in PBL and the particular skills that are developed in the process include the development of student's critical thinking ability, ability to analyze and solve real-life complex problems and use of suitable resources to work in teams, reflecting both communication and intellectual skills to become effective learners. Vila et al. (2017) stated that PBL is a method of instruction that allows students to work in groups with collaboration that helps them identify their learning needs to solve a complex problem, engage in independent learning, apply their personal knowledge to solve a problem and reflect on the learning process as well as the effectiveness of the used strategies. The authors also highlighted that PBL is both "knowledge-based and process-based" in the sense that the learners need to be evaluated on both these dimensions to ensure if the PBLapproach is beneficial for them or not. In addition students' responsibility for the curriculum content and their ability to recognize their learning content needs to be assessed.

In response to the changing learning demands of the 21st century, several educational institutions across the world have adopted a curriculum that is based on a scientific approach including multiple learning styles. These learning models are known as "project-based learning and problem-based learning" the application of which is expected to help in the development of the skills of students, particularly in terms of their ability to think critically, create innovatively, learn effectively and adapt to changes swiftly. PBL equips students to deal with real-world situations through the exchange of information with fellow students and teachers which influences their thinking ability as well as learning outcomes (Wan Husin et al., 2016). According to Chu et al. (2017), the instructor plays a key role in facilitating the process of learning through PBL. Therefore a set of PBL goals are developed by the teachers to help students develop " flexible knowledge, effective problem-solving skills, effective self-directed learning skills, effective collaboration skills, and intrinsic motivation." Flexible knowledge combines information from different areas and incorporates them into the learner's memory. Such knowledge needs to be systematically organized around deeper aspects of the subject matter and students develop such knowledge through the application of their knowledge in multiple situations. Besides this, the development of effective problem-solving skills is yet another goal that refers to the learners' ability to appropriately apply the strategies namely, "metacognitive and reasoning strategies" (Hmelo-silver & Eberbach, 2012).

According to Skliarova (2021), PBL includes a number of dimensions like "tutorial process, facilitation, problems solving, collaboration, self-directed learning, and post-problem reflection." Through the tutorial session, minimal information regarding a complex problem is presented to a section of students and these students engage in experimentation, research, or questions to gather additional information about the problem. At different intervals, students pause to analyze the collected data, develop questions and hypothesize the causal relationships that exist within the data. In this manner, their understanding of the problem and progress towards finding a solution is evaluated. Shpeizer (2019) further highlighted the concept of "collaborative problem-solving groups" in PBL and observed that a small structured group helps in distributing the workload among the group members effectively, thereby making use of the whole group's expertise in finding solutions to the problem at hand. This feature of diving into the learning problems enhances the "higher-order thinking" of students and promotes the construction of knowledge sharing. Therefore Sharma et al. (2020) stated that in the context of engineering education also such collaborative PBL methods prove to be beneficial for not only the students but also the teachers at large since the expert solutions are later used in learning pedagogies and generalized for the world of engineering.

Mann et al. (2021) presented a framework of PBL and validated its implementation through a case study of the Engineering Practice Academy at Swinburne University of Technology. According to the researchers, the implementation of PBL is most commonly undertaken using a "blank slate" method and as such, the PBL framework in the Swinburne University of Technology was also established along with the prevailing engineering programs. The Academy is unique as an organization and operates as an engineering practice, delivering solutions to clients across industries and communities in conjunction with the PBL framework to provide students with the opportunities to not only learn but also work simultaneously in an authentic setting. The Academy offers a space for collaboration among the academic community, specialist "engineers in residence", professional staff and associates/students. Although the associates of the Academy enrol as students in engineering honours, they learn and work in the academy entirely as associates. The academy has been primarily created to serve as a functioning engineering practice and not just to provide an authentic setting for working and learning but also to deliver meaningful results for both industry and community partners. The main aspect of the PBL framework which is supporting the learners towards achieving their goals of becoming professionals is central to the Academy. The academy's primary purpose is to establish such associates who can become professional engineers and who can constitute what counts in the process of engineering education. The PBL framework of the academy uses the term "associate" for learners as it challenges the lexicon, thereby encompassing both the identity of the associates and the expectations of the society which further empowers associates to think, work and behave like professional engineers in the Academy's practice-based context. Under this framework, the associates learn through "self-driven and personalized learning journeys, defined in their Individual Development Projects, micro-credentials, through which they develop knowledge, skills and capabilities and their context as associates of the Academy positioned within the Swinburne University of Technology, where they are recognized as learners by the University and external peers."

2C. Implementation of Digital PBL

According to Lei (2010), the problems are given to learners only after the dissemination of information via lectures fail to optimize information availability and accessibility. Therefore the implementation of PBL helps in student empowerment by providing improved accessibility, larger knowledge, the discovery of the sources of sharing knowledge, propagation of knowledge and knowledge enterprise with the help of the use of "learning management systems, Web-based learning and Internet communication." Liljaniemi & Paavilainen (2020) observed that the processes of PBL offer multiple opportunities for the educational institutions to make use of the "learning management systems (LMS)" presently available. LMS tools such as "WebCT, Topclass and Blackboard" offer excellent service for the dissemination of information and problems, accessing e-learning resources and website linkages as well as discussions among learners and teachers (Barber et al., 2015). According to Lindgren & McDaniel (2012), the use of PBL requires the "initiative, ownership and independence" of students for facilitating the process of learning through digital platforms. Although the concept of PBL is more learner-oriented, the role of instructors is crucial in the development of the learning environment and facilitating "communication, problem inquiry, critical evaluation and metacognition." The digital platforms enable students to carry out discussions and chats with a group of fellow students in a hassle-free manner (Warter-Perez & Dong, 2012).

As observed in the study conducted by Chen (2021) in PBL students engage in practising both "thinking strategies and domain knowledge." PBL approaches specifically advocate education that is based on experiences. Therefore PBL is a significant development in the realm of education that has a major impact on the varied disciplines, the students as well as teachers. Considering these aspects, various forms of virtual learning environments in educational institutions have warranted the incorporation of PBL into their learning pedagogies for improved access to PBL based learning (Boss & Krauss, 2014). According to Gan, Menkhoff & Smith (2015), digital learning or e-learning is facilitated with the help of multiple forms of technology with most of them using different combinations of techniques such as " blogs, collaborative software, e-Portfolios, and virtual classrooms." Since PBL is most commonly used in higher education, the development of a virtual learning environment is most crucial for higher education institutions, especially in the present era of "Web2.0 technology" (Chua et al., 2018). Educators across the world have started introducing "Web 2.0" tools to enable the creation, collaboration and sharing of learning experiences (Fernandez-Sa et al., 2013). As observed in Gomez-Pablos (2017) study, the "Moodle's Learning Management System (LMS)," a cutting edge e-learning technology was implemented at Massey University which has been extensively used since then for the delivery of collaborative PBL learning both with regard to internal as well as distance learning across the different fields of courses and programs of the university. Following this, the digital learning platforms have begun to be used as teaching tools for delivering PBL based learning to students. The author thus stated, "the more the focus is on developing students who can devise effective solutions to real-world problems, the more successful those students will become" (Francese et al., 2015).

Gupta, Mukhawana & Mashinini (2019) reported that the use of PBL through digital platforms had a positive impact on the motivation of pre-service teachers to teach more scientific and experience-based ideas to the students. According to Fleaca & Stanciu (2019), a digital learning environment has been defined "as one that affords the potential to carry out asynchronous and synchronous learning, while problem-based learning (PBL) is used as the process to implement the planned scenarios, such as case studies, as well as to aid learning in a multidisciplinary or multi-skills context." Kulanidhi et al. (2020) explored the perspectives of students on the transformation brought by the digital learning environment in higher education and observed that students believed that the use of digital platforms for delivering PBL learning has successfully transformed the education system as the benefits of PBL can be better achieved through the use technology.

In the face of the digital age universities across the world are confronted with the challenge of recognizing the future job profiles and their skill requirements and therefore adapting and adjusting their education curriculum, content to include them. In conjunction with this, Louw & Deacon (2020) presented a case study and stated that in most engineering programs, in order to achieve their engineering degree students need to complete a final year project which is an independent project developed and executed by the students under their guide's supervision. The main aim of such projects is to reinforce the skills gathered by students during the course of the program, demonstrate the application of the skill, knowledge and tools they have been exposed to as well as gain new skills. The researcher described a project in which the student had to develop a semi-automated robotic cell for the SLF. The student not only had to demonstrate the project but also further develop the business and design competencies as well as the problem-solving skills, metacognitive skills, systems thinking as well as technological literacy skills. "New technical skills also had to be developed related to digital-to-physical transfer technologies (additive manufacturing in this case), data communication and networks, automation, robotics, and programming skills (related to robotics and internet-of-things)." This clearly indicates how the university allowed the students to practically explore and discover what is actually required so as to simulate an actual industry experience where it is otherwise difficult to define the exact problem and task and comprehend the exact requirements of the users. Therefore the implementation of digital PBL in engineering education programs is clearly reflected in the study.

2D. Challenges and Future Prospects

The invention of ICT has made education easy through digital learning. Although technology in the realm of education has been used across different educational settings across the world, there are multiple challenges associated with its implementation (Guo et al., 2020). Gohmann (2017) stated that one of the major challenges of shifting PBL from the setting of a traditional classroom to that of a digital setting is that students fail to engage in group projects conveniently and finish them together. Lin (2018) also stated that teachers find it challenging to make instant assessments of students' competencies in projects through online PBL. However, a study conducted by Viksne et al. (2016) stated that PBL through online platforms had a positive effect on students as they showed a better understanding compared to the traditional classroom settings.

According to De Los et al. (2015), the challenges of PBL through digital platforms faced in engineering education are not just specific to this field but also relevant across all other fields of education. At the individual level lack of teacher training for digital platforms poses one of the major challenges as without the absence of the theoretical and practical knowledge and skills of the online PBL methods the teachers are unable to design the activities of the course, facilitate teamwork among students and fails to draw a balance between influencing and helping in the work of students (Jamaludin & Sahibuddin, 2012). Therefore to improve the implementation and effectiveness of PBL, pedagogical training to engineering teachers should be provided in the future so that they gather knowledge and skills regarding the use of digital tools for PBL (Jayasainan & Rekhraj, 2015). Lee et al. (2014) highlighted that the unpreparedness of the teacher towards digital PBL is highly responsible for the absence of student preparation as they fail to make use of the available digital tools and the necessary technologies needed for their projects effectively. Karabulut-Iglu et al. (2018) stated that when the necessary milestones for the projects are not set by the instructors and proper guidance is not provided to the students through the digital platform, the tendency of a shift in focus occurs among students and they fail to follow any rubric thus making the whole process unsuccessful. Therefore Kiray et al. (2013) stated that the need for training is necessary for students as well when the PBL environment shifts from traditional classroom settings to an online platform. This could be done through the promotion of self-learning, or in the form of workshops, seminars, meetings, etc. According to Li & Faghri (2016), the lack of adequate support from education institutions also poses yet another challenge for the implementation of PBL through digital platforms. According to Qadir & Al-Fuqaha (2020), the COVID-19 pandemic has posed a major challenge for educational institutions across the world as the physical form of education came to a standstill with almost 70 percent of the total enrolled students globally getting affected and more than 150 countries facing complete closures of schools. However, although the education sector has been jolted by the pandemic, the transition to distance learning and online education due to the presence of the Internet has subsided the challenges associated with the situation a little even if not entirely. In the context of engineering education it has been observed that in such a volatile, uncertain, complex, and ambiguous (VUCA) situation that the pandemic has brought on us, it is imperative to carefully evaluate what it takes to be an effective engineer. According to the authors, the wide adoption of digital PBL during as well as beyond the pandemic is one of the top changes in the system of engineering education especially with PBL being the underlying mechanism followed by the globally accredited universities. Incorporating digital PBL in engineering education institutions during COVID-19 depends on various factors such as g state policies, pedagogical methods used by the instructors, and the wide availability of digital technologies. Although virtual labs and simulations cannot replace hands-on experience with real-life divides and tools in the world of engineering education, it largely bridges the gap in learning and experience in times when there is a major disruption in the physical presence of learners due to health concerns, Several companies such as MATLAB and National Instruments provide part of their services through web-based cloud services. Adedoyin & Soykan (2020) stated that for the purpose of online teaching in the times of COVID-19 educators need to necessarily adhere to the triple imperatives namely the equity imperative, inclusion imperative and the effectiveness imperative. In addition to this, for engineering education to thrive in particular during COVID-19 more awareness of the digital PBL paradigm is needed along with significant metacognitive and learning proficiency.

Grodotzki et al. (2021) in their study stated that the outbreak of the COVID-19 pandemic triggered a major shift towards online education and forced educators across the world to transition into digital forms of teaching. However, the brunt of this transition was mostly felt among teachers at technical universities who had to switch to digital PBL tools and techniques to ensure the delivery of the best possible learning experience for engineering students. Virtual laboratories were designed to meet the learning goals of the students depending on their level of accuracy and the complexity of a project. Teachers started familiarizing students with virtual machines which could be later used for hands-on or remote laboratories. Further, the principal steps of experimentation were made available to students virtually so that they get an experience of a real lab. The authors observed that COVID-19 led to a global spread of the digital PBL method among engineering institutions providing students with the best experiences of conducting their projects without making them feel the absence of a real lab. It offered them a flexible schedule to stay motivated and track their progress and served as a platform of information conveyance as well as interaction.

Mielikäinen (2021) stated that the COVID-19 pandemic has accelerated the global transition to digital learning particularly digital PBL in the realm of engineering education where experiments and projects are a fundamental part of the curriculum. Education in the engineering field requires a broad range of software, hardware devices and tools as a result of which it is essential for this the sector to step up to the challenges posed by the current scenario and offer a digital curriculum that is properly equipped to offer new and up to date technologies for experiments and projects to take place virtual;y. This relevant curriculum has been implemented in the majority of the technical institutions and the study points out the case of Aalborg University which has implemented a digital curriculum based on various levels of integration between the projects and the courses and the use of PBL in the integrated Game Development and Entrepreneurship program of the University of Ontario's Institute of Technology.

According to Kapilan et al. (2021), engineering education is dependent on laboratory experiments as it helps students in gaining experience through concrete materials, improves their problem-solving skills of students, enhances their abilities to understand practical problems and improves their attitude towards education. However, the COVID-19 pandemic considerably affected this sector of education as students were not able to attend laboratory classes. Hence the training of faculty members to adopt digital PBL through virtual laboratories and other such software began and it accelerated even more with the further implementation of lockdowns. The students were provided classes on theory as well as the demonstration of experiments via virtual platforms. The faculty members were given full training on

Table 1 : Challenges and Future Prospects

Challenges	Future Prospects
Lack of real -world connection: Digital PBL connects students with the real world.However, when PBL lacks real -world connection it can lose the ability to motivate students to indulge in deeper learning (Zafirov, 2013).	New possibilities for teaching and l earning post - Covid-19 due to the significant shift in online learning (Randazzo et al., 2021)
Focusing on Products over processes: At its core, PBL is a powerful inquiry -driven learning process. The engagement of students in the inquiry process involves guiding them to ask meaningful questions to examine compelling real - world problems (Hakkarainen, 2009).	Online learning will foster self-directed learning skills as part of the pedagogical process. Students in online courses will develop self - directed learning skills as they keep track of assignments, manage their time due to the flexibility of online lectures, and initiate engagement with peers and the instructor (Yousef et al., 2014).
Assessing individual learning through group work: Both formative and summative assessment of individual learning is done through PBL. However formative assessment is particularly important to enable students to identify and address gaps in learning (Rohm et al., 2019).	Hands-on learning via problem or project -based learning will increase self - efficacy in students. Research self -efficacy is one's beliefs regarding their ability to carry out research related tasks (Lambie et al., 2014).
Neglecting to build a collaborative classroom culture: Digital PBL involves a team -focused environment however it can create challenges for them and for the overall classroom management (Oliveira et al., 2013).	Students will report greater satisfaction with PBL in an online course as measured by their ratings of the usefulness of their assignments, the likelihood of engaging in research and doctoral study in the future, and open -ended comments (Randazzo et al., 2021).

simulation, measurement and remote triggered Virtual Learning experiments.Similarly, engineering students were trained on different aspects of the digital platforms where the virtual experiments would be induced. Therefore it has been observed that the pandemic led to the increase in the use of virtual laboratories in engineering education thereby giving the realm of digital PBL a further push that greatly affected the learning process of engineering students ever since.

It has been observed that the pandemic will trigger multiple economic, social and technological developments that are projected to drastically reshape education, especially in the field of engineering and computer science in the next few decades due to the (Hai et al., 2021).). According to Froyd et al. (2014), engineering education leaders such as IEEE should make significant decisions regarding the manner in which they undertake the initiatives of innovation and support to enhance engineering education at such unprecedented times.Table no. 1 below represents the challenges and future prospects.

3. Research Gap

The existing literature on the area under investigation has been reviewed thoroughly. However, several lacunae have been observed in the process as a result of which the findings of the study are equivocal. Although there exists a better understanding of PBL, there still exist multiple gaps that need to be addressed. Since studies on problem-based learning through digital platforms are very few, the knowledge regarding its technical details is also very limited. An absence of formal research indicates that a number of questions about the subject matter remain unanswered.The existing literature clearly explains the concepts of problem-based learning, its different components and its relevance in the field of education. However, studies with special reference to digital PBL in the context of engineering education are very few. As a result of this, the results of the study are more generalized instead of being more specific to engineering education. The implementation of the new PBL that is more digital in nature is contextually more appropriate in its disciplinary, institutional, social, and cultural environment. To date, the research on the impact of digital PBL on student learning has been scarce as in research on types of problems and types of implementation. In order to gain a detailed insight into what specific implementation types or features work under certain conditions, a clear understanding of the context is imperative because imprecise descriptions could hinder the validity of the review. Although the existing PBL research has confirmed that PBL is highly effective in cultivating the collaborative skills of students, there is a paucity of research on interdisciplinary curriculum design and implementation. The literature also highlights the several challenges of the digital PBL curriculum, however, it fails to address the challenges posed by external conditions, including a higher ratio of students and teachers, absence of a teamwork infrastructure, and absence of technical support for conducting digital PBL and its associated financial challenges. Although the literature stated that the primary objective of digital PBL is to facilitate the development of real engineers, in most cases there exists a lack of involvement in terms of community and industry, and the academic outputs of students have limited chances of being used in professional real-world settings.

Various sub-components of PBL are being increasingly delivered with the help of Digital PBL. The realm of digital education is transforming and the manner in which PBL is conducted is experiencing a paradigm shift due to this transformation in the digital education world. However, most researchers have only concentrated on PBL as an iterative process of delivering education while ignoring the digital aspect of this domain. Studies on the application of digital technologies in PBL based learning have hardly found a place in the existing literature although there is increasing evidence of different applications of digital technology in PBL. It is therefore still unclear as to how effective it is to incorporate digital technology within the domain of PBL as compared to traditional PBL. Therefore it is recommended that future studies potentially integrate the components of digital PBL as well as blended PBL to deliver education, especially in the technical fields such as that engineering education.

Furthermore, a broad range of research methods could be employed to address the "why" questions for clarification purposes of the phenomenon of PBL in the engineering education context. For instance, qualitative research methods will help in relieving the details for explaining the observed data. Qualitative research could be more flexible in capturing the dynamic nature of digital PBL during the process. Therefore the diversification of research methods and tools will help in seeing a complete picture of digital PBL.

4. Research Methodology

Since this study aims to capture and review the interpretations of different researchers on PBL and digital PBL and identify its current status, challenges and future prospects in the realm of engineering education, the overall process of development of this review paper has been based on the relevant study selection. For the purpose of attaining a comprehensive and in-depth understanding of the concept of PBL and digital PBL, its current status, its implementation in the engineering education setting, relevant factors and challenges and future prospects, relevant studies have been selected and such articles, papers have been researched that broadly discussed the significance of the topics and citation of the same have been done in relevance to the current area under investigation.

A comprehensive review of the literature has been performed by researching articles, books, journals, case studies, and conference papers to assess relevant information and data from early 2012 to 2021. 2012 was used as the starting year so as to show the evolution of PBL in the realm of engineering education over a period of a decade till 2021. The data and study materials were limited to the English language based on the relevant keywords related to the concept under study. Based on the literature, the research performed primarily included the following terms and keywords related to the topic which were used in various combinations such as engineering education, problem-based learning, project-based learning, digital problem-based learning, online learning, virtual learning, online PBL, PBL implementation, challenges, COVID-19, pandemic. Using these keywords, over 50 previous and existing research studies were identified and selected for conducting the review.

The process of selection was a meticulous one. There exist several guidelines for selecting the data in systematic reviews, especially while conducting research in the field of medical and engineering education. The first step involved the identification step which encompassed the search for research items that are most relevant to the pre-established objectives of the study. The second step involved the screening phase wherein a list of potentially relevant research items was analyzed for content that perfectly fits the objectives of the study. The third and final step involved the disclosure of the review sample wherein the final review sample is rendered. Prominent disclosure of the entire list of research items included in the review is mandatory else the readers have no idea regarding the research items that can be used for building the basis of the results of the review. These three steps have been conducted in a manner that ensures that the overall sample selection is in alignment with the three attributes of the reviews which include structure, transparency and comprehensiveness. Furthermore, the database was used for the purpose of searching the items in google scholar. The keywords and related search helped in identifying, grouping and segregating the studies. The titles, abstracts, and the main body of the articles and journals were carefully and thoroughly checked to judge their relevance. The final selection of around 74 previous studies is based on the data grouped into separate themes such as the concept, current trends and status, driving elements, contributing factors, and the implementation of the strategies related to digital PBL in the realm of engineering education, particularly in the times of the ongoing pandemic. After the selection of final studies, a review of the studies has been performed to understand the concept highlighted in research studies through a careful inspection. This procedure was helpful in performing the analysis of the studies to deduce relevant data. Furthermore, the population involved in the majority of the studies selected, mainly consisted of students, such as undergraduate students and undergraduate engineering students in particular.

The analysis of all the studies has been performed to interpret relevant information and data that can facilitate valuable conclusions. An additional data search has been conducted within the selected papers to identify those specific data which can assist in further analysis and discussion. Although the studies selected are diverse in nature, the outcomes reveal the trends specifically with regard to PBL, digital PBL, its implementation in engineering education, the challenges associated with its implementation and future prospects in the field as a result of the outbreak of the COVID-19 pandemic.

However, there were certain limitations in the search such that the detailed insights into the selection of the samples and the previously mentioned implications do not complement the existing methodological advice on carrying out systematic reviews in engineering education research. This, therefore, needs to be kept in mind for future research while conducting another systematic review on such topics.

5. Conclusion

A detailed review of the several aspects of problem-based learning through digital platforms pertaining to engineering education has been conducted in the paper in which new and innovative ideas and suppositions have been established thus making it a comprehensive research framework. Multiple contributions have been made in different aspects of the area under investigation, some with regard to existing knowledge and trends while others pertaining to modern and contemporary approaches and propositions, in order to create a fresh research framework that has not been attempted before. The implementation of digital PBL will help in preparing teachers for this trend and therefore understanding ways to design successful digital PBL is necessary. Digital PBL will contribute towards a more concise understanding of the concept by educators to deliver education. Perceived collaboration and technology is important to be taught in a transdisciplinary manner as a result of which it is an important component of any curriculum. Digital PBL will make the process of delivering presentations more creative and innovative thereby enabling the improvement of PBL efforts by teachers. The collaboration aspects of PBL will largely impact teachers' perceptions of how to implement PBL in their classrooms and technology will significantly assist them in this process.

From the perspective of students, digital PBL will serve as a useful medium for the development of the skills of students. It will help in improving their understanding of the applicability of a concept in real-life situations. Furthermore, it will also boost the students; confidence to assess the tools for the future and be more creative in making presentations and delivering them. Therefore in conclusion it can be said that there exist multiple broad implications that can be drawn from this review which will significantly assist both teachers and students to improve the learning environment through practices such as collaboration, enabled by technology. The constant use of digital PBL and support adjusted to educators in the classroom as well as the school context is necessary.

The existing literature helped in providing an insight into the key concepts of engineering education, effective learning practices, problem-based learning, problem-based learning in the digital context, and its various components, and explored the differences in the implementation of digital PBL by providing an overview of the current PBL implementation-related challenges which could inspire the future design of PBL practice. The literature review further highlighted that the concept of digital PBL is most widely used in the context of engineering education as technological advancement warrants the implementation of digital PBL in this field to explain the real-world situations to the students in an improved and more technologically advanced manner and generate real engineers who would have the potential and competencies to radically shape the field of engineering.

Since digital PBL includes diverse and multiple digital technology applications as part of traditional PBL it is more effective than the traditional form of learning and improves the "post-intervention learning outcomes" of students. Although the evidence for other outcomes such as "satisfaction, attitudes, cost-effectiveness, and adverse effects" are limited, it is observed that these variables have some effect on digital PBL. However, there is enough scope for the evaluation of digital technology-based PBL delivery of education and its effectiveness, especially in technical fields like engineering education.

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