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Designing blended learning platforms: A focus group study with educators

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A B S T R A C T

The COVID-19 pandemic accelerated the use of digital technologies, such as blended learning (BL), in higher education. These technologies support educators in designing personalized learning experiences and help digital-native students prepare for future leadership roles. This study used focus group discussions (FGDs) with three groups of higher education educators to explore their views on BL in engineering education. The FGDs included open-ended questions focusing on the complexities and challenges of adopting BL and on how technology might help address these issues. The transcripts of the discussions were carefully read several times, coded, categorized, and analyzed to identify key themes. In addition, the participants' facial expressions were observed and considered in the analysis. Based on the findings, a design framework was developed for creating an online learning platform in engineering education. The results show that integrating BL into education provides significant benefits for both educators and students.

1. Introduction

Since the outbreak of the COVID-19 pandemic, the field of higher education has been marked by a profound shift towards the integration of digital technologies. This shift not only reflects the far-reaching impacts of the COVID-19 pandemic, but also that the field of higher education is now seamlessly connected to the vast resources of the Internet. More specifically, educators have adopted blended learning (BL) as a revolutionary teaching method and seamlessly integrated it into traditional classrooms to create dynamic online activities and customized learning environments. BL also offers online resources that increase opportunities for customized learning and flexible instructional methodologies with measurable cost reductions (Sidi et al., 2023). Their study highlighted that the shift to BL encouraged educators to streamline content delivery, improving efficiency while accommodating different learning preferences.

BL combines digital activities with face-to-face courses. In the context of engineering education, this not only enhances traditional learning by incorporating new elements and industry-related challenges but cultivates advanced problem-solving skills (Sala et al., 2024). This approach is becoming increasingly prevalent in institutions of higher education. More specifically, in the field of engineering, educators can create challenging scenarios that reflect real-world industry problems to actualize the intended learning outcomes (Sala et al., 2024). BL accomplishes this by leveraging technology to simplify concepts, incorporate current information, and provide virtual, hands-on experiences that address individual learning needs, improve accessibility, and encourage collaboration among learners (Basitere et al., 2023).

BL enhances education by integrating digital components and fostering collaboration via interactive technologies, such as clickers and online labs, as well as virtual experiments and simulations (Graham and Halverson, 2023; Rossiter, 2020; Wang and Wang, 2023). Artificial intelligence (AI) and automation were initially viewed as a threat. However, they are now seen as complementary to traditional teaching methods as they enhance access to resources, the production of quizzes, and student-educator communication (Rossiter, 2020; Wang and Wang, 2023). However, AI-based optimizations risk oversimplifying complex concepts, which would undermine the critical thinking skills of the students. As such, robust monitoring methods, such as external evaluations and peer reviews, must be put in place to maintain the high quality of a BL environment (Graham and Halverson, 2023).

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Therefore, educators must ensure that the use of AI supports learning rather than impedes it.

The key challenges to implementing BL in institutions of higher education include inadequate access to the Internet, insufficient information and communication technology (ICT) infrastructure, limited technological skills among educators, and the lack of calculated training and support (Stephen and Makoji-Stephen, 2023; Thahir et al., 2023; Wang and Wang, 2023). Therefore, institutions must be equipped with a comprehensive technological infrastructure to provide educators with comprehensive BL-related training. Students and educators must also be able to communicate effectively for BL to be successful. Therefore, all the individuals involved must firmly commit to a student-centered pedagogy to successfully navigate BL (Mavuso and Jere, 2022; Thahir et al., 2023).

Digital natives are the defining characteristic of today's educational landscape. They are capable of not only easily navigating the digital realm but also effectively harnessing the resources of the Internet as well. Apart from that, the demand for online courses has also surged. As such, BL has become an increasingly vital approach and an integral component of higher education. This has prompted educators to adopt BL to elevate the quality of their teaching.

BL integrates various applications in a seamless way, including Google Docs, Sheets, Slides, Forms, Meet, and Hangouts (Li et al., 2024), as well as Padlet, which is a collaborative virtual board used for adding notes, graphs, videos, and other multimedia content.

Virtual learning systems (VLS) and virtual labs are technologies that enhance BL. VLS enables educators and students to collaborate effectively by creating educational settings that are flexible (Abuhlfaia and de Quincey, 2019; Arango-Vasquez and Manrique-Losada, 2022). They support a diverse range of educational content as well as improve student-educator communication. Apart from that, VLS provides students with quick access to materials and enables educators to easily share resources. This not only saves time but also makes education more affordable and accessible.

VLS also significantly decreases the space- and equipment-related costs of education (Abuhlfaia and de Quincey, 2019; Arango-Vasquez and Manrique-Losada, 2022; Arisandi et al., 2023). These studies support the view that virtual systems not only reduce physical constraints but also improve access to materials, collaboration, and real-time communication between students and instructors. These factors could create a decisive shift towards a more inclusive and flexible educational model. VLS also addresses the evolving needs of educators and students. It enables them to transition from traditional teaching methods to more modern, technology-enhanced learning environments. However, there is still some room for improvement in terms of how it can best support teaching and learning in the field of engineering education.

The primary objective of the present study was to gain a comprehensive understanding, primarily from the perspective of educators, of the requisites for the successful implementation of BL in the field of engineering education. As such, focus group discussions (FGDs) were conducted with them to gain insights into the intricacies of BL, the unique challenges it presents in the domain of engineering education, and the role of technology in mitigating these challenges. A design framework for creating a virtual learning platform for engineering education was then developed.

The present study is organized into several sections. Section 2 details the methods used to conduct the FGDs, while Section 3 presents the results and findings of the FGDs. A discussion that delves into the key findings and their broader implications is presented in Section 4. Section 5 describes the proposed VLS design framework, while Section 6 contains both a summary of the key takeaways of the present study as well as considerations for future research.

2. Methods

Three FGD sessions were conducted with a total of ten educators in July 2023. Most of the participants were affiliated with the engineering faculty of a university. These participants were intentionally selected from diverse age groups, genders, and ethnicities who had taught engineering-related courses and had experience in BL.

The FGD technique was selected as it is an informal approach that yields the perspectives of participants by eliciting their spontaneous reactions and ideas (Ochieng et al., 2018). It also allows for in-depth discussions and the drawing of subjective opinions during candid discussions among peers.

Each FGD session lasted between 60 to 90 minutes, with a moderator skillfully guiding the conversation to ensure productivity. The FGDs were scheduled to ensure that the participants were available to participate. At each session, the participants introduced themselves and shared their experiences with reinforced learning in engineering courses. This was followed by in-depth discussions with the moderator posing several open-ended questions and guiding the conversation without dominating it. This encouraged the participants to actively share their perspectives, comments, and opinions.

Each discussion was meticulously documented through audio recordings and subsequent transcriptions. Notably, the focus was on vocal expressions during the discussion. Subsequently, the detailed notes from each FGD were cross-referenced with the corresponding audio recordings to ensure accuracy. The FGD transcripts underwent multiple readings to identify recurring themes, factors, and diverse responses. This qualitative data was systematically coded and categorized to facilitate analysis. Thematic analysis was conducted following the six-phase process of thematic analysis, including data familiarization, initial coding, theme identification, reviewing, defining, and reporting (Braun and Clarke, 2006). The transcripts were coded using NVivo software, applying both inductive and deductive coding strategies. Initial codes were independently developed by two researchers using an open coding approach. These were then discussed and refined collaboratively until agreement was reached. A thematic map was also created to organize and connect major themes. Coding reliability was ensured through peer debriefing and independent cross-checking of codes by a second researcher to enhance consistency.

The third focus group reached thematic saturation, as no new themes or concepts emerged in subsequent discussions. This indicated that sufficient depth and breadth of data had been achieved. Triangulation was achieved by comparing audio transcripts, field notes, and observations during the sessions.

3. Results

Although 14 educators were invited to participate in the FGDs, only 10 were able to attend. Table 1 presents the participants' characteristics.

Table 1: The characteristics of the 10 participants

Category	No.
Department	
Department of electrical and electronic engineering	3
Department of accounting and finance	4
Department of mechanical engineering	2
Department of engineering foundation and general studies	1
Gender	
Male	5
Female	5

The results of the FGDs were categorized into four prominent themes, namely the benefits, challenges, technological tools, and future of BL. These themes were derived from the comprehensive responses and insights shared by the participants during the FGDs.

3.1. Benefits of blended learning

All the participants acknowledged the significant benefits of BL. Notably, they emphasized its transformative role in engaging students who are otherwise shy or reluctant. This was because the tools that are integrated into BL provide these students with a comfortable platform to actively contribute to discussions and garner peer feedback, thereby enriching their overall learning experience.

One participant succinctly defined BL as "time-saving and provides instructional benefits." They went on to state that BL is a boon. It is a valuable assessment tool as it takes less time than manual marking." Educators prefer to use tools, such as quizzes and assignments, not only to save time, but also to make students more accountable for their own assessments. Another significant advantage of BL is the ability to share diverse materials, such as text, visuals, and graphics, which makes it particularly valuable in certain subjects. A participant echoed these sentiments by explaining that BL seamlessly integrates electronic tools into the traditional classroom environment. This enables students to supplement their paper references with a wealth of electronic resources, which not only improves their understanding of the course material but also their overall learning experience.

A common characteristic that was universally acknowledged by all the participants was the unique flexibility of BL. According to a participant, "Compared to conventional approaches, learning management systems (LMS), such as Moodle, make it easier to share notices and updates." Apart from that, it also enables students to revisit and review lessons at any time, thereby promoting self-directed and independent learning.

This self-paced learning structure is central to the personalized learning experience that BL offers. BL provides students with access to video recordings and other resources that they can revisit as needed. According to the participants, BL allows students to study at their own pace, ensuring that no student is left behind. This is a significant advantage, particularly for students who are slow learners. One participant noted that, "In a classroom of 50 students, each would prefer a different learning style. BL accommodates these varied learning styles, allowing students to access and utilize materials in a way that maximizes their benefits." This is noteworthy as it is impossible to replicate in a traditional classroom setting.

Another participant highlighted how BL ensures that students are not confined to static class materials. BL allows for the integration of current issues into the curriculum, fostering more critical thinking, in-depth discussions, and a proactive learning environment. A BL environment enables students to think beyond textbooks, explore problem-solving, and engage with emerging technologies and lifelong learning tools that they will utilize in the future.

These many insights collectively underscore the manifold benefits of BL. BL provides a platform for reserved students to participate actively, offers time-efficient assessment tools for educators, facilitates the sharing of diverse learning materials, ensures flexibility and access, and promotes personalized and differentiated learning. As such, BL is an indispensable tool in modern education as it equips students with not only contemporary knowledge, but with the critical thinking and problem-solving skills necessary for navigating the future as well.

Based on the thematic analysis of the FGD, participants consistently identified several key benefits of BL. These included enhanced student engagement, improved assessment efficiency, greater access to diverse learning materials, increased flexibility, and support for personalized and self-paced learning. Fig. 1 presents a thematic summary of these perceived benefits, grouped according to patterns that emerged during the analysis.

Fig. 1 illustrates five core benefit categories, with supporting participant quotes and examples structured under each theme. This visualization reinforces the frequency and consensus around these advantages.

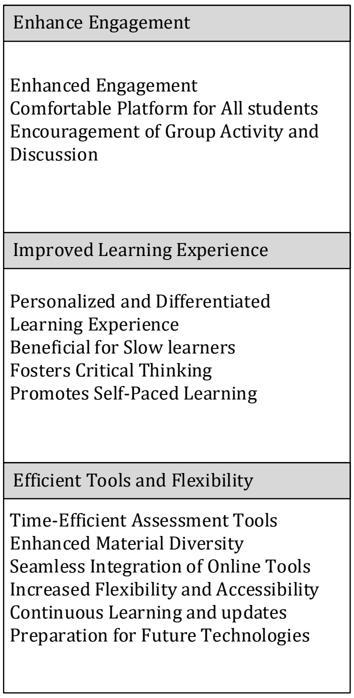

Fig. 1: Key benefits of blended learning (BL) based on focus group analysis

However, although BL has many benefits, its success is contingent on several factors. For one, institutions play a critical role in promoting BL adoption. According to one of the participants, "The institution should always encourage this BL. However, much more encouragement and support are needed from the institution." Nevertheless, there is palpable momentum for its adoption. For instance, according to another participant, "Over 92.5% of our academics managed to implement BL successfully."

3.2. Challenges of implementing blended learning

The participants highlighted numerous challenges with BL implementation. A central concern was the imperative for sufficient technological infrastructure and resources. The participants voiced concerns about "unequal access to technology and Internet connectivity" among the students, highlighting a critical digital divide.

They also stated that there is a need for 'better clarity', especially when navigating the intricate levels of BL. This is because the integration of diverse online platforms presents its own set of challenges. For instance, the common concerns that exacerbate difficulties surrounding Internet connectivity and device limitations. These problems are further compounded by students' overwhelming use of smartphones, which makes it particularly difficult to fully encourage student engagement via cameras, which is vital for effective two-way communication.

Even though educators have transitioned to various online platforms, such as Zoom and Microsoft Teams, this introduces a "steep learning curve" and impedes the ability of educators to communicate with their students smoothly. Apart from that, disruptions within the various home environments of the students, as well as the lack of real-time interaction, further impede the teaching process.

Pandemic-induced shifts in the assessment process, more specifically, a greater reliance on online submissions and Internet-based references, have added another layer of challenges. As such, the participants stated that there is an urgent need for thorough support and revolutionary strategies with which to navigate the BL landscape effectively.

The participants also stated that it was challenging to align the multiple online materials with the specific learning objectives of each course. The new tools or concepts uncovered in prior courses only made it more challenging. As such, some of the participants had to bridge the knowledge gaps that the multiple online materials created.

However, unlike the educators, the students adapted to the BL approach surprisingly quickly. Their resilience and resourcefulness were further underscored by their active engagement in discussions while simultaneously seeking additional information from various online sources. They also benefited from the supplementary materials. This, ultimately, strengthened their overall comprehension of newer and unfamiliar topics. Therefore, this is a beacon of hope for the potential success of BL.

In addition to the benefits of BL, participants identified several key challenges that hinder its effective implementation. These were consistently discussed across all focus groups and fell into three primary categories: technological issues, planning and implementation barriers, and pedagogical challenges.

Fig. 2 illustrates these themes by organizing participant feedback into structured categories. For example, technological challenges included infrastructure gaps and device limitations, while planning issues referred to navigating blended levels and shifting lab content online. Pedagogical concerns centered on aligning new tools with course objectives and teaching complex concepts in engineering contexts. This thematic categorization reflects the coded data structure that emerged during analysis.

3.3. Technological tools in blended learning

BL has become an integral part of engineering education at universities. This is highlighted by the selection of technological tools and platforms that are tailored to enhance the learning experience.

According to a participant, “Students are very critical of every educational institution. As such, we need to adopt a good functioning LMS.” The university adopted a Moodle-based learning management system (LMS), which was subsequently rebranded as Brighten, to streamline its educational platforms and decrease inconsistencies.

The university has made it compulsory for all lectures and academic activities to be conducted through the LMS.

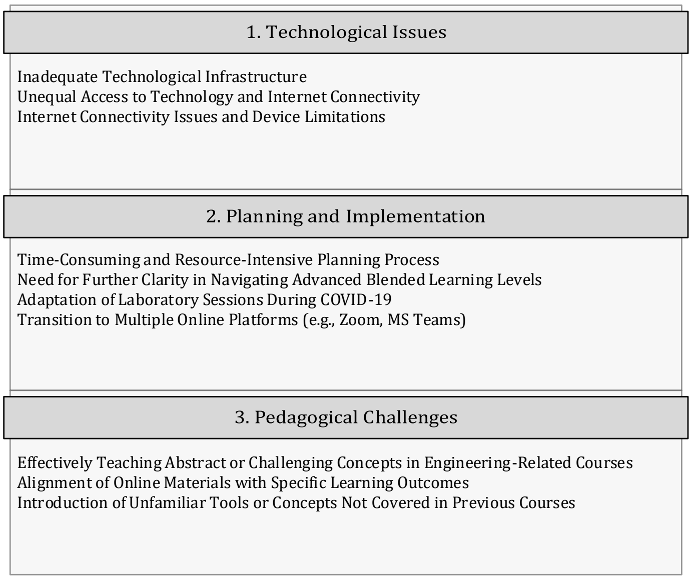

Fig. 2: Key challenges in implementing blended learning (BL) based on focus group analysis

The teleconferencing tools that engineering universities use were also discussed. Despite an initial preference for Zoom and Google Meet, most of the universities eventually transitioned to using Microsoft Teams. This choice was driven both by the institutions’ decisions and by individual faculty members. According to a participant, “We are very comfortable using Microsoft Teams.” Another participant mentioned that their institution uses Panopto, a video management system, to host all their lecture videos. This caters to two types of educational content: standard lecture recordings and shorter asynchronous videos for bite-sized learning.

The participants also stated that other tools, such as Padlet, are used to enhance student learning and create collaborative canvases, while MindMap, Mentimeter, and Genially are used to create engaging courses. However, these tools are exclusively used for micro-credentials and open-distance learning. One participant enthusiastically stated their affinity for Genially, saying, “The tool I love to use for BL is Genially, an app with which I can create interactive content.” Meanwhile, platforms, such as OpenLearning, which support online courses, are used to supplement traditional teaching.

GeoGebra was another tool that the participants highlighted. It offers visualization capabilities, particularly for three-dimensional graphs, which enable the students to grasp complex concepts more easily. One of the participants stated that they utilize “GeoGebra to illustrate three-dimensional graphs for the students. So that they can better understand what the surface looks like and what an object looks like? I think that’s very useful, and it is free of charge.” Another participant spoke about the versatility of Moodle, detailing its ability to seamlessly deliver content to students, even those who join the courses late. According to the participant, “We can put in a lot of different content into Moodle and let the students learn it themselves.”

Artificial intelligence (AI)-based tools can also be used for educational purposes. For instance, one participant shared that they told students to use ChatGPT to answer a set of questions. The students were required to use their critical thinking skills to determine the accuracy of the information provided by ChatGPT.

The multitiered approaches that engineering universities used to adopt BL were also discussed. This comprised the various stages, ranging from basic document uploads on the LMS to more advanced adaptive learning techniques. According to one of the participants, “There are four stages. The first stage is the basic stage, where the lecturer uploads the documents to the LMS. Then, we had some training to upskill the lecturers to the BL level, where they did online activities in the LMS. We also empowered them with further training in level three, which was flipped teaching and learning. Then, there’s level four, which was adaptive learning.” The commitment of the institution to BL was further emphasized by the unique framework that it introduced in 2016, which, according to one participant, “is a framework with supports in many terms and in many aspects.” Training, pedagogy, and tool utilization were pivotal for realizing the objectives of the framework.

One participant passionately remarked, “We have encountered tools that have truly transformed our educational approach, such as interactive maps. These maps not only visualize data, such as tracking greenhouse gas emissions across Malaysia, but also foster engagement. Students can delve deeper into regions, understand the nuances of energy consumption, and even discover success stories in the renewable sector. This tool embodies our vision of integrating technology with education to create a dynamic and interactive learning environment. When our students click on a specific region of the map, they're not just accessing data; they're embarking on a journey of exploration and understanding, and that's the essence of modern education at engineering-based universities."

This example reflects broader themes discussed across the focus groups. Participants consistently highlighted a wide range of digital tools that support BL in engineering education.

Fig. 3 provides a summary of these tools, grouped by their primary function, such as content delivery, engagement, assessment, and data tracking. These categories reflect the participants' emphasis on using technology not only to transmit information, but also to foster active learning and monitor student progress. Tools like LMS platforms and animation resources were noted for improving content access, while gamification and AI tools were praised for boosting motivation and learner autonomy.

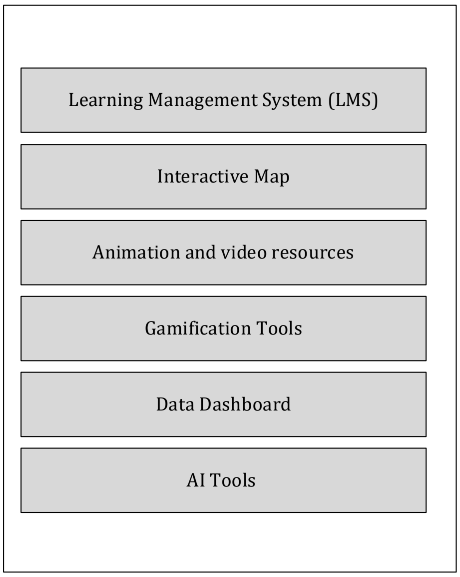

Fig. 3: Key technological tools supporting BL in engineering education

3.4. Future of blended learning

The ever-changing educational environment underscores the dynamic nature of BL, which is shaped by its established practices. The insights gleaned from the FGDs revealed that BL stands at the edge of shaping the future of modern education, especially in engineering education.

However, several challenges remain. According to one of the participants, "I remember this now that I mentioned the current state of awareness among the community. They are not savvy when it comes to engineering education. There's a disconnect between the industry, or perhaps what the nation wanted, as well as the level of awareness." This highlights the pressing need for more awareness and initiatives to address this gap. Therefore, by combining digital strategies with conventional pedagogical methods, BL can be a bridge with which to address this cognitive gap and craft a community that is more adept in an engineering context. For engineering education, in the future, the participants recommended combining digital strategies with pedagogical approaches to improve education.

However, the views of one of the participants contradict this perspective. According to this participant, "The level of awareness of engineering education concepts is high now. However, society must be aware of the situation of a variety of engineering fields that exist locally and globally." Nevertheless, with BL, academic institutions can remain agile and recalibrate their curricula in real-time to reflect prevailing engineering concepts.

Apart from that, the participants noted the essential role that technology plays in BL adoption. According to one of the participants, "You must be able to get by with some tools, for example, MATLAB and Microsoft Excel." Therefore, BL is not only a convergence of the digital and physical realms but also a symbiotic alliance that uses various technological tools to enhance pedagogical efficacy.

The global post-pandemic reflections were voiced by another participant who remarked, "After lockdown, world leaders realized that this could be an opportunity for us to change the way we operate, with the relevance of engineering education remaining intact." This fortifies the adaptability and relevance of BL as it is a strong model that is congruent with global transitions. For instance, one participant shared that educators faced difficulties with the physical lab during the COVID-19 lockdowns. As such, they used virtual labs and VLS to continue engineering education.

The findings of the FGDs underscore the transformative potential of BL, particularly in the field of engineering education. This is because BL promises to nurture generations that have flexible global outlooks, are informed and engaged, and fully educated by integrating customary classroom practices with online strategies, such as VLS.

4. Discussion

The findings of the FGDs delineate the evolution, intricacies, and potential of BL in engineering education. Several critical themes emerged, namely, the benefits, challenges, tools, and technologies used in BL, as well as its future. These findings echoed, expanded upon, and sometimes diverged from extant literature on BL.

Participants widely agreed that BL is a vital approach in engineering education, offering enhanced student engagement, greater flexibility, and improved learning outcomes—making it integral to their teaching practice (Dumford and Miller, 2018; Lewohl, 2023). However, the participants also listed several challenges, such as technical issues, planning and implementation difficulties, pedagogical challenges, technology integration, teacher training, and the design of effective online content (Truss and Anderson, 2023). Notably, engineering universities that adopted a structured, phased approach to BL successfully addressed recurring challenges through strong technical support, continuous faculty training, and collaboration with IT—offering a replicable model for other institutions.

The emphasis that BL places on a student-centric approach represents a profound shift away from traditional teaching methods. Historically, educators dictate the pace, content, and method of education delivery. However, in BL, students are given more agency and flexibility to choose how, when, and where they engage with educational materials.

The current global trend prioritizes active participation, with educational strategies significantly influencing this shift. Learner autonomy is also increasingly prioritized (Alrabai, 2021; Hu and Zhang, 2017). These studies collectively emphasize that when learners are given the freedom to control their pace and access resources independently—especially in blended formats—they tend to show higher motivation, stronger retention, and improved satisfaction. For instance, it is believed that learners who have a say in their education have significantly better outcomes, such as overall satisfaction, knowledge application, and retention.

The results of the present study demonstrate that using data in conjunction with tools, such as interactive maps, reflects a broader trend in education that leverages technology to enhance cognitive engagement. This aligns with industry standards in areas such as engineering and addresses global calls for cross-disciplinary curriculum alignment. It particularly aligns with the unique demands of engineering education, where complex datasets and simulations are essential for applying theoretical concepts (Sala et al., 2024) and preparing students for their future professions. Apart from that, allowing students to engage with the educational material ensures that the data tools that they are using correlate with industry-relevant skills and applications.

The results of the present study also reveal the great potential of BL in bridging the gap between digital strategies and traditional teaching methods. However, challenges remain, particularly in community awareness of engineering education. Therefore, several initiatives are required to not only improve awareness but also align education with industry needs. Nevertheless, despite these challenges, several participants noted increased awareness of engineering concepts. They also stressed the role of BL in enabling institutions to update their curricula rapidly. Apart from that, the participants also highlighted the overall importance of technology in BL and how tools, such as MATLAB, are crucial for effective teaching.

The COVID-19 lockdowns improved the adaptability of BL, with virtual labs and VLS serving as alternatives when traditional labs could not be used. This underscores the transformative potential of BL in engineering education, as it promises to create students who are not only knowledgeable but adaptable and prepared to meet the demands of the modern world as well.

The results of the present study offer practical and real-world perspectives for consideration. The FGDs also improved our comprehension of BL. The participants stressed that BL is not simply about integrating online resources but about doing so in a meaningful manner to ensure relevance to the subject matter, industry standards, and students' needs. Therefore, this provides a framework that institutions wishing to transition to or enhance their BL initiatives can use.

BL can be further enhanced by combining it with VLS-based frameworks. This would enable educators to create tailored and immersive experiences that address the practical aspects of engineering education. It would also make BL a robust tool for both theoretical and hands-on learning. This combination would not only optimize BL but also provide clear guidelines for application developers to create systems that meet the specific needs of educators. The participants also indicated the need for a structured framework with which to effectively implement and optimize BL in engineering education. The following section outlines and demonstrates the VLS framework that the present study proposes to address the identified needs and challenges. It also provides a comprehensive guide for both educators and developers.

With respect to the scope of the sample, some limitations must be acknowledged. While the study involved a relatively small group of ten educators from engineering disciplines, this aligns with the qualitative research paradigm, which emphasizes depth of understanding over statistical generalization (Cresswell, 2013). Participants were purposefully sampled to ensure diversity in gender, experience, and discipline within the engineering context, thereby maximizing the richness of insights obtained. The focus group method facilitated in-depth discussions and generated context-rich insights into participants' experiences and perceptions of BL.

Although the findings may not be generalized to all educational contexts, they offer transferable knowledge that could inform BL strategies in similar higher education environments. Given the exploratory nature of the study and the alignment with qualitative research norms, the insights are considered credible and meaningful within engineering education. To enhance the breadth and applicability of future research, we recommend involving a more diverse sample of educators from multiple disciplines and institutional types. Such expansion would allow for comparative analysis and empirical validation of the proposed framework across broader educational settings.

The proposed Virtual Learning System (VLS) framework emerged from the thematic analysis of educators' discussions during the focus groups. Each of its components was grounded in participant experiences and substantiated by supporting literature. Although not yet empirically validated, its structure reflects recurrent patterns and needs articulated by educators during FGDs. The framework can serve as a foundational prototype to guide future research and instructional design.

Validation of this framework could be pursued in subsequent phases of research through expert panel reviews, Delphi studies, or pilot implementation in engineering courses. Feedback from instructional designers and engineering educators can further refine the framework to improve its relevance and usability in diverse higher education contexts.

Given the exploratory nature of the study, the framework is intended as a foundational structure that can be refined and validated through subsequent work. Future research may include expert panel evaluations, pilot testing in academic settings, or cross-disciplinary comparisons to assess its relevance and applicability across diverse educational contexts.

5. Proposed virtual learning system's design framework

The VLS framework presented in Fig. 4 was developed based on the thematic findings of the FGDs, supported and enriched by relevant literature. The six dimensions reflect participants' shared perspectives and are intended to guide the design of effective BL platforms in engineering education.

These dimensions include user interface and experience, infrastructure and technical support, content development and management, assessment and feedback, learner engagement, and immersive learning environments. Each component captures a core requirement for a virtual learning system and was identified as critical by participants during discussions. Fig. 4 visually presents the conceptual structure of this framework, which serves as a foundation for future design, implementation, and validation of VLS models in engineering contexts.

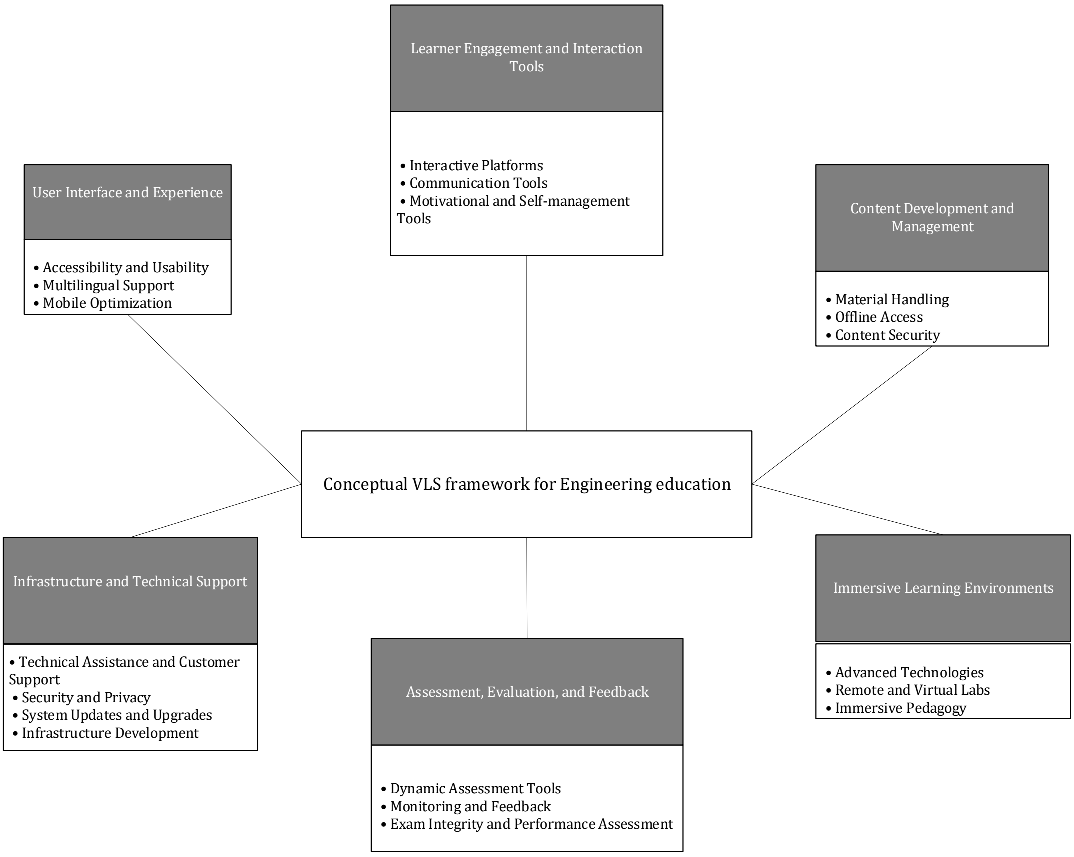

Fig. 4: Conceptual virtual learning system (VLS) framework for engineering education

These dimensions were derived from both participant input during FGDs and a synthesis of the existing literature. The framework comprises six dimensions, namely, (1) user interface and experience, (2) infrastructure and technical support, (3) content development and management, (4) assessment, evaluation, and feedback, (5) learning engagement and interactive tools, and (6) an immersive learning environment. Each dimension contains further subdimensions that enhance the roles of the VLS. A comprehensive review of extant literature underscored several essential dimensions that are integral to a VLS framework. For instance, the user interface and experience dimension stresses that usability and accessibility across user types and various devices are vital. Apart from that, multilingual support and mobile optimization are required to transcend language barriers and facilitate the widespread use of smartphones (Chuaphun et al., 2024; de Oliveira et al., 2020). Therefore, the user interface should support self-paced learning. More specifically, students should be able to access and interact with materials via interactive quizzes and real-time feedback mechanisms. In terms of infrastructure and technical support, a strong infrastructure that can handle private data and provide frequent updates is required to facilitate a smooth user experience (Bolu et al., 2020; Ong and Hawryszkiewycz, 2003). The results of the present study highlight the importance of addressing technological inequities and ensuring that each student has access to the necessary resources. Therefore, support must be provided in underserved areas. Apart from that, both educators and students should be given sufficient training so they can use VLS tools and platforms effectively.

The participants also highlighted the importance of offline access to materials and decreasing connectivity issues, as it supports continuous learning. They also stated that diverse content formats and alignment with course objectives are crucial for enhancing both students' engagement and learning outcomes.

Assessment and feedback mechanisms are essential for ensuring a fair and thorough evaluation. Therefore, a certain level of learning must be supported, and academic integrity must be maintained through real-time feedback mechanisms and dynamic assessment tools (El Habti et al., 2022; Roopchund, 2022). According to the participants, online assessments, computerized grading, and a streamlined evaluation process would decrease the burden on educators.

Learning engagement and interactive tools create educational settings that are interactive and engaging. When platforms such as Kahoot! MATLAB and Moodle are used in conjunction with real-time communication tools, which improve students' participation and motivation (Faza et al., 2021). The participants noted that motivational resources, along with essential tools, promote active participation in constructivist educational settings.

Educational settings that are engaging leverage the dimension that advanced technologies, such as virtual reality, augmented reality, and remote laboratories, provide to offer a hands-on learning experience. Students who are engaging in practical experiments, as well as those who understand complex concepts, would particularly benefit from these technologies (Mehrtash et al., 2021). Virtual labs ease practical learning. According to the participants, some students grasp engineering concepts better with this sort of assistance.

Therefore, integrating these dimensions into a VLS framework would strengthen BL as well as improve students' educational experience by making it more inclusive, effective, and engaging. It also ensures that VLS is a strong and adaptable learning system with which to support the ever-evolving needs of both educators and students. As a conceptual model, this framework provides a comprehensive foundation for guiding the design, development, and empirical testing of virtual learning systems tailored for engineering education.

6. Conclusion

The present study conducted FGDs with 10 educators from an engineering university to identify the benefits and challenges of implementing BL in engineering education. It was also used to understand the need for such a VLS framework, the technological tools and resources used, and future perspectives in engineering education. The participants highlighted the many advantages of BL, primarily that it effectively engages students who are reluctant to participate in a traditional classroom setting. BL encourages students to actively participate in learning, personalizes certain experiences, and provides flexible access to course materials. However, various challenges were identified, namely, the need for strong technological infrastructure, students with unequal access to technologies and the Internet, and difficulty adapting laboratory sessions for complex topics, especially during the COVID-19 pandemic. It is also difficult to overcome learning curves and engage in diverse online activities via BL.

The participants stated that a VLS framework for engineering education should provide a clear direction as well as standardize and incorporate the best pedagogical practices. They also listed LMS, animation, interactive maps, gamification, and data dashboards, as well as various technological tools and resources, as the key components of BL. The participants also emphasized that engineering education remains crucial in addressing multiple national and international environmental challenges as well as engineering-related uncertainties. These findings provide valuable insights for other engineering educators, who can use these findings to ensure that their students have productive learning experiences. Lastly, future research could validate the proposed VLS framework and explore its impact on student learning outcomes. They could also examine incorporating emerging technologies into their features.

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Compliance with ethical standards

Ethical considerations

All participants were informed about the purpose of the study, and their voluntary participation was ensured. Informed consent was obtained prior to data collection. Participants were assured of the confidentiality and anonymity of their responses. No personal data was disclosed, and participation had no potential risks or harm to the respondents.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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