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Rethinking Evolution Of Active Learning In The Hybrid/Online Engineering Education In The Post-COVID-19 Era: A Quantitative Keyword Co-Occurrence Analysis

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ABSTRACT

In response to COVID-19, education witnessed a rapid shift to online and virtual platforms. Our previous research has raised questions about the efficacy of these methods for hands-on practice and active learning experiences - crucial elements of engineering education. Emergent solutions like online laboratories and virtual field trips have led to the rise of a hybrid learning era in the post-pandemic context. This change necessitates a reassessment of active learning in hybrid/online engineering

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education. In this study, we examine recent literature on online and virtual education during and post-COVID-19 to redefine and reevaluate strategies for engaging students actively. We propose using VOSViewer to analyze the occurrence of keywords in post-COVID-19 literature to define a visualization between the interests in research and the content of key papers in situating active learning for hybrid/online education. We analyze the evolution of active learning theory, outline its characteristics in the new era, and propose a literature review focusing on how digital technology can synergize with learning approaches to foster active learning. We also address concerns related to hands-on practice and active learning and discuss innovations developed to mitigate these challenges. Our goal is to provide fresh insights and stimulate further research on enhancing active learning within hybrid/online engineering education in the post-pandemic era.

1 INTRODUCTION

With the World Health Organization declaring the end of the global COVID-19 emergency, engineering education has predominantly returned to on-campus settings. However, the three-year stint of online education during the pandemic has irrevocably changed the educational landscape, transitioning away from a strictly campus-centric learning environment (Gratchev and Espinosa 2022). Many institutions continue to offer a variety of online learning resources, fostering an environment where traditional campus and online/blended education coexist.

Our previous work, conducted at the onset of the pandemic, highlighted concerns regarding the development of social and practical skills in online engineering education due to the implementation of technological platforms as means for replacing communication platforms rather than as a learning tool (Piyatamrong et. al 2021). Solutions leveraging active learning strategies were proposed to address these concerns, such as virtual labs promoting constructivist thinking and active experimentation in online settings (Radhamani et al. 2021). Accompanying videos demonstrating procedures align with active learning strategies as they allow students to replicate processes autonomously by guiding their learning journey (Gratchev and Espinosa 2022). However, these studies were conducted during enforced quarantine, necessitating a reevaluation of active learning strategies within online/hybrid engineering education in the post-epidemic era.

This paper's objective is to revisit active learning in the context of online/hybrid education during and after the pandemic. We will discuss strategies to overcome the limitations of hands-on active learning and propose the concept of technology-mediated active learning. The paper unfolds in three stages. Initially, we will investigate the definition of active learning in engineering education, discussing its essence and the challenges COVID-19 has posed. Subsequently, we will analyze engineering education literature from the pandemic period to discern key strategies identified as facilitating active learning. Finally, we synthesize the findings, emphasizing the coexistence of hybrid/online and traditional engineering education in the post-pandemic era. We'll reconsider the definition of active learning and propose technology-mediated active learning as a promising opportunity for future developments in engineering education.

1.1 What is Active Learning in Engineering Education

Active learning has been defined as the "intelligently guided development of the inherent possibilities of everyday experience" (Christie and De Graaff 2017). Several methods of active learning exist, including project-based learning, flipped classrooms, and collaborative or cooperative work. Researchers have demonstrated the benefits of active learning in various types of engineering education through extensive literature reviews using diverse quantitative and practical methodologies (Lima, Andersson, and Saalman 2017). Hernández-de-Menéndez provides a comprehensive perspective on active learning in engineering education, describing it as an interactive, highly engaging, and student-centered approach that promotes learning through meaningful hands-on activities and critical thinking (Hernández-de-Menéndez et al. 2019). In this model, students are motivated to learn, the work is focused on learning objectives, and the instructor assumes the role of mentor and evaluator of progress.

While definitions may vary, most scholars concur that active learning implies student autonomy and promotes active cognitive engagement. Some researchers have narrowed the scope of active learning to classroom activities (Lombardi et al. 2021), conceptualizing it as either individual or group tasks that involve all students in class proceedings, wherein teachers process students' feedback and alternately provide novel information and instruction (Felder and Brent n.d.). On the other hand, Charles C. Bonwell has expanded the definition of active learning, categorizing any activity that provokes students to engage in reflection and critical thinking as active learning (Frost 1991).

Engineering education is highly structured and integrated, emphasizing the evaluation of project outcomes to gauge the understanding of course content and knowledge of diverse attributes. The teaching process also involves imparting abstract knowledge, such as engineering ethics and humanistic values. Given these characteristics, engineering education underscores the importance of independent study and scenario-based learning, thereby aligning closely with the tenets of active learning.

1.2 What Challenges COVID-19 Brings To Active Learning in Engineering Education

Our prior research (Piyatamrong et al. 2021) highlighted that the abrupt transition to online education at the onset of the COVID-19 pandemic was necessitated by the urgent need to ensure educational continuity. We observed that communication platforms such as Zoom and Microsoft Teams were swiftly repurposed as substitutes for in-person instruction. Yet, in the initial stages of the pandemic, these adaptations resulted in a loss of informal interactions between students and faculty, along with diminished opportunities for active learning and practical experience. In parallel, other studies, such as that by Seraj et al. (2022), reviewed pedagogical trends and assessment practices during the pandemic, capturing insights from both students and teachers. While several advantages of online learning were recognized—ranging from positive teacher-student experiences, and cost and time savings, to flexible and collaborative learning environments—concerns were also raised. These included issues related to academic support, learner autonomy, student-centered approaches, timely teacher responses, and the capability for ubiquitous learning in the online environment during the pandemic.

From a technological implementation standpoint, concerns were centered around the integration of courses with technology, internet connectivity, lack of interaction, technical infrastructure deficits, device unavailability, inadequate training, and motivational challenges. These findings, resonating with our research, suggest that the use of digital technology in online education presents notable challenges for active learning. We aim to further investigate the relationship between the realization of active learning and the application of digital technology in online education, drawing upon various scholarly publications.

2 METHODOLOGY

2.1 Research Design

This study employed keyword searches to identify pertinent literature sources for review. Given the narrow scope of this review and the specificity of the topic, the review's focus was to ascertain the relationship between active learning and technology-mediated education in online/hybrid engineering education during COVID-19. Therefore, a keyword search was utilized as an efficient strategy to promptly identify the most recent and relevant articles on this topic (Levy and J. Ellis 2006). Scopus was chosen as the database for this review due to its robust quality, diverse multidisciplinary journal coverage, and swift literature update frequency (Chadegani et al. 2013). From the database, 150 papers published between 2021 and 2023 were selected. The literature selection process was partitioned into three steps.

The first step centered on the identification of five keywords based on the review topics: COVID-19, learning and technology, technology-mediated education, engineering education, and active learning. Boolean operators were utilized in searches to include all potential keywords, thereby minimizing the risk of omitting critical papers. 'Online learning' and 'hybrid learning' were introduced as search keywords to generate a wider range of relevant papers. The inclusion of 'online learning' as the sixth keyword and the application of filters on the social science, engineering, and computer science subject categories yielded 225 results. When 'online learning' was replaced with 'hybrid learning', maintaining all other keywords and filters, 20 results were produced. In the second stage, the results from both searches were combined, and duplicates were removed, resulting in 230 relevant papers. The third stage involved a rigorous limitation of subject categories, excluding all articles unrelated to social science, engineering, and/or computer science. This led to a final selection of 150 articles. Considering that the keyword 'COVID-19' inherently signifies a specific time zone, all retrieved search results were published between 2021-2023, aligning with the review's temporal constraints. Consequently, all articles were deemed appropriate for inclusion.

2.2 Data Analysis

Keyword co-occurrence analysis is a robust method in bibliometrics, instrumental in evaluating the interconnected conceptual structure of research topics (Radhakrishnan et al. 2017). Therefore, this study utilizes VOSviewer (Van Eck and Waltman 2010) for a quantitative keyword co-occurrence analysis. The software's sophisticated algorithm identifies clusters of keywords, represented by distinct colors, and calibrates the interrelationships among these keywords. The software-generated map exhibits these connections through label sizes, keyword nodes, and lines connecting these nodes. The frequency of keywords can suggest the popularity of a particular topic. Furthermore, the clusters depict which keywords are frequently associated, while the connecting lines illustrate the strength and nature of these relationships (Van Eck and Waltman 2014).

From the 150 references selected for this study, 839 keywords were extracted. Initially, a minimum co-occurrence rate of 3 was set for the keywords, of which 66 satisfied this criterion. The second stage entailed a manual screening process to eliminate words with overlapping meanings (e.g., 'covid-19 pandemic', 'pandemic') as well as words deemed irrelevant or overly general (e.g., 'teacher', 'student', 'learning'). Lastly, total link strength attributes demonstrate the total strength of an item's links with other items (van Eck and Waltman, n.d.). Keywords with a total link strength of less than 6 were eliminated, as this insufficient connection strength suggested the keyword's lack of relevance to others. The remaining 36 keywords were deemed significant and were subsequently utilized for analysis.

3 RESULTS

3.1 Finding

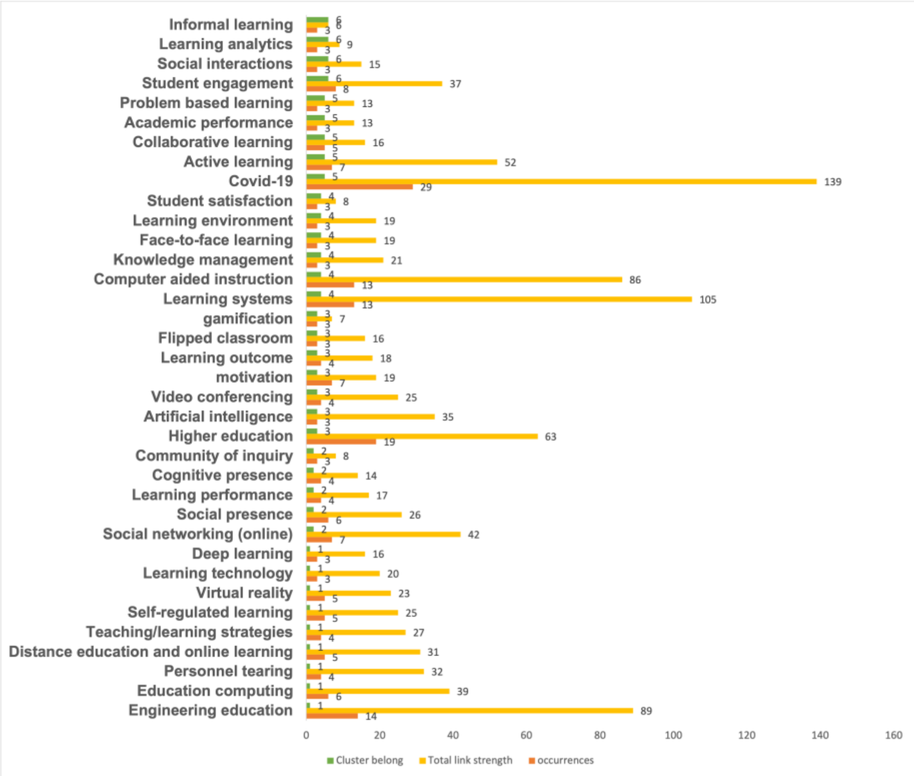

Fig. 1. Co-ocurrency analysis and cluster classification

Figure 1 presents the analyzed keywords, their occurrence frequency, and their total link strength along with the cluster classification. The table reveals six keyword clusters, each containing a comparable number of keywords. This suggests that the six research categories connected with this topic carry equivalent significance. Clusters 1, 3, and 5 represent novel technologies in hybrid/online engineering education pertinent to practical skills during the pandemic, such as educational computing, virtual reality, artificial intelligence, video conferencing, and gamification. These emerging technologies are integrated into traditional active learning strategies like the flipped classroom, self-regulated learning, deep learning, motivation, collaborative learning, and problem-based learning.

Cluster 2 elucidates concerns in hybrid/online engineering education related to social networking (online) and social presence, alongside some active learning-related solutions such as cognitive presence and the community of inquiry. Cluster 4 illustrates the aspects of active learning in engineering education that have been affected by COVID-19, encompassing learning systems, learning environment, and student satisfaction. Lastly, Cluster 6 describes the specific attributes of active learning in hybrid/online engineering education during the pandemic, focusing on student engagement and informal learning.

When sorted in descending order based on total link strength, and excluding keywords used in the literature search, the most prominent keywords are learning systems, computer-aided instruction, higher education, social networking (online), education computing, student engagement, artificial intelligence, personnel training, social presence, self-regulated learning, video conferencing, and virtual reality. The most researched themes in active learning in hybrid/online engineering education during the pandemic, incorporating these keywords, are social skills concerns, technology strategies for practical skills, and the characteristics of active learning.

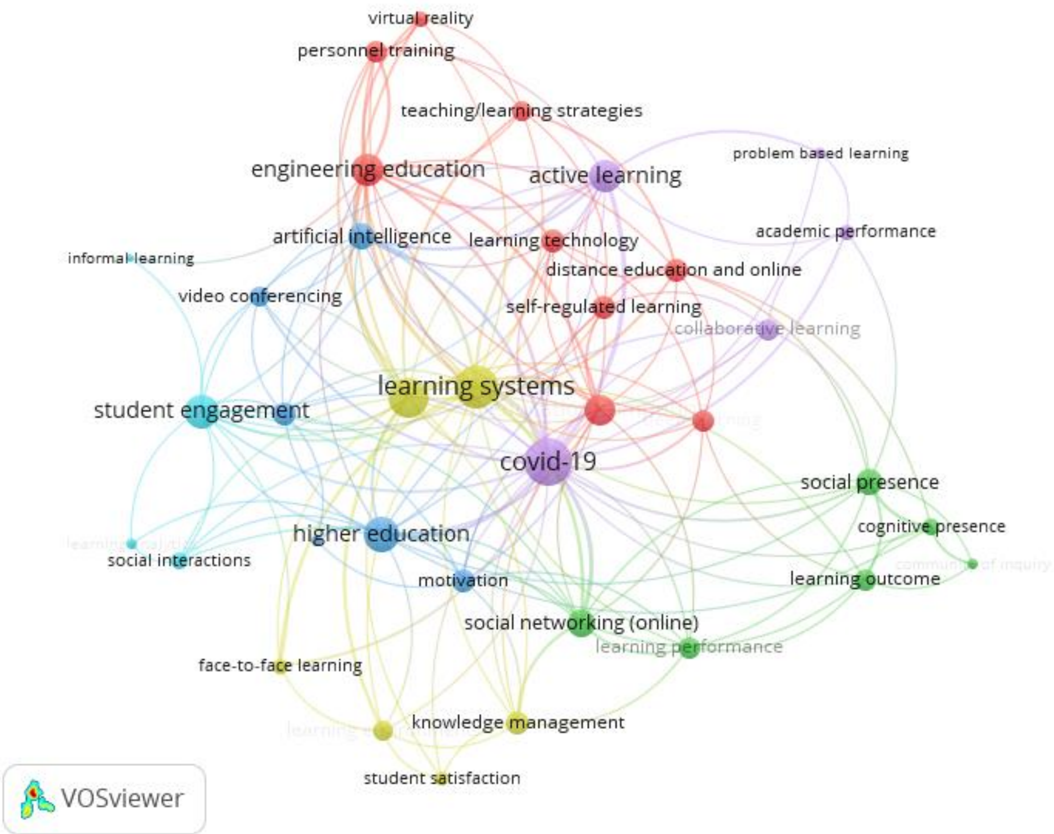

Fig. 2. Keywords mapping

The keyword connection map is depicted in Figure 2, where the colors represent various word clusters, the size of the label represents the number of other keywords linked by the word, and the lines represent the keyword connections. As illustrated in the figure, keywords with numerous connections to other keywords span across different word clusters. These prominently interlinked keywords include COVID-19, active learning, learning systems, computer-aided instruction, student engagement, and engineering education. Moreover, all word clusters contain multiple keywords linked to other clusters, corroborating the potent relationship between hybrid/online engineering education, active learning, and technology.

Through the combined analysis of word clusters and keyword link strength in Figure 1, along with the visual representation of interconnections in Figure 2, it can be inferred that in the research conducted during the pandemic, social skills and practical skills emerged as paramount challenges for active learning in hybrid/online engineering education. Further, novel technical strategies, such as virtual reality, artificial intelligence, and video conferencing, have been proposed due to their alignment with active learning principles. These strategies are anticipated to tackle the issues associated with social and practical skills.

3.2 Discussion

In the post-pandemic era, hybrid/online engineering education will exist alongside traditional engineering education, thereby transforming the landscape of campus-based engineering education. Our study highlights the increased usage of innovative technologies, including Web technologies, virtual laboratories, and virtual reality to foster active learning, both from the standpoints of student learning and pedagogical methodologies. The technological advancements utilized during the pandemic have offered fresh insights into the future direction of active learning.

In our search of keywords among various literature discussing the proposed topics, we see centroids of keywords surrounding learning systems, learning technology, and student engagement as a central bridge between clusters of other keywords. This suggests the need to explore the literature on digital tools promoting learning systems, learning technology, and student engagement to critically think about how the tools can promote active learning and what challenges they could bring to hybrid/online engineering education.

It is apparent from this study, and the literature, that a range of digital tools have emerged that can support active learning within the context of online engineering education. Foremost among these are interactive simulations and virtual labs, which have been found to be as effective as physical labs in promoting learning outcomes (Ma and Nickerson 2006). These tools allow students to manipulate variables, conduct tests, and observe results in real-time, thereby providing a hands-on experience within a virtual environment. Moreover, the principles of gamification can also be incorporated to enhance the interactivity and engagement of online learning. By integrating game-based elements, the learning process becomes more immersive, thereby fostering active participation, increasing motivation, and improving knowledge retention (Huang and Soman 2013). The technologies of Augmented Reality (AR) and Virtual Reality (VR) further extend these interactive capabilities. In engineering education, AR can be utilized to visualize complex structures, while VR can enable students to practice skills within a safe, simulated environment (Radianti et al. 2020).

However, the feasibility of implementing such advanced tools in every class session could be challenging, hence, to explore the promotion of active learning for engineering education in hybrid/online learning, we suggest various approaches to enhance student engagement and create a learning system. Discussion boards and forums, for example, can facilitate active learning by encouraging students to engage in intellectual discourse, debate concepts, and pose inquiries. Platforms like these can also facilitate peer feedback, a key element in the learning process (Garrison, Anderson, and Archer 2000). Adaptive learning platforms have also shown promise, using algorithms to tailor the learning experience to each student's needs, thereby offering personalized feedback and resources. This approach ensures the material is appropriately challenging, promoting active learning without overwhelming students.

Collaborative tools, such as Microsoft Teams (Romadhona and Dwiningsih 2021), can further enhance this experience by enabling group projects or brainstorming sessions and fostering critical thinking skills (Johnson, Johnson, and Stanne 2006). The responsibilities for promoting student interactions and the effectiveness of active learning systems through discussion boards, forums, and adaptive learning platforms will depend greatly on the skills and encouragement of the lecturers. This, therefore, emphasizes the need for greater technological and pedagogic support for lecturers in designing and running blended and hybrid course modules based on active learning.

4 CONCLUSION

The paper contributes a new quantitative literature analysis perspective that reflects the growth of active learning in blended/online engineering education in the post-pandemic era. However, the research methodology is not without limitations. For instance, the use of a single database and keyword search may result in the omission of relevant literature, leaving space for improvement in future research. In conclusion, the use of technology in online engineering education introduces a variety of strategies for active learning, each with its distinct advantages and challenges. As we navigate the post-COVID-19 landscape, the careful selection and application of these methods become crucial in fostering active learning and enhancing the quality of education. The responsibility increasingly falls on educators to rethink the interactions between students and teachers, and among students themselves, as well as to redesign pedagogical approaches. The goal is to shift from considering digital tools as simple communication platforms to recognizing them as platforms for implementing integrated learning systems. By doing this, we can fully harness their potential to achieve active learning objectives, thereby bringing about significant change in the field of education.

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