The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #43631

Teaching Online Engineering: A Systematic Literature Review

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Youla Ali, a Junior majoring in Computer Science at the University of Oklahoma, currently serves as a Research Assistant in the Engineering Pathways program under the mentorship of Dr. Javeed Kittur for the academic years 2023-2024. Her research focuses on online engineering education, driven by her desire to understand the challenges that instructors face when transitioning course components, such as experiments and labs, to remote formats. As an engineering student herself, Youla aims to offer valuable insights into effective online teaching strategies. She wishes for her contributions to enhance course interaction and ensure student perseverance in asynchronous engineering education for peers who rely on online learning options.

In summer 2023, Youla was awarded a fellowship by The Office of Undergraduate Research and Creative Activity (UReCA) at the University of Oklahoma. This fellowship enabled her to complete a Systematic Literature Review on asynchronous online engineering education under the title "Teaching Online Engineering: A Systematic Literature Review". Her research has contributed to identifying emerging themes in six finalist scholarly papers on asynchronous online engineering education and has offered significant Research and Practice Implications for these themes.

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Dr. Kittur is an Assistant Professor in the Gallogly College of Engineering at The University of Oklahoma. He completed his Ph.D. in Engineering Education Systems and Design program from Arizona State University, 2022. He received a bachelor's degree in Electrical and Electronics Engineering and a Master's in Power Systems from India in 2011 and 2014, respectively. He has worked with Tata Consultancy Services as an Assistant Systems Engineer from 2011–2012 in India. He has worked as an Assistant Professor (2014–2018) in the department of Electrical and Electronics Engineering, KLE Technological University, India. He is a certified IUCEE International Engineering Educator. He was awarded the 'Ing.Paed.IGIP' title at ICTIEE, 2018. He is serving as an Associate Editor of the Journal of Engineering Education Transformations (JEET).

He is interested in conducting engineering education research, and his interests include student retention in online and in-person engineering courses/programs, data mining and learning analytics in engineering education, broadening student participation in engineering, faculty preparedness in cognitive, affective, and psychomotor domains of learning, and faculty experiences in teaching online courses. He has published papers at several engineering education research conferences and journals. Particularly, his work is published in the International Conference on Transformations in Engineering Education (ICTIEE), American Society for Engineering Education (ASEE), Computer Applications in Engineering Education (CAEE), International Journal of Engineering Education (IJEE), Journal of Engineering Education Transformations (JEET), and IEEE Transactions on Education. He is also serving as a reviewer for a number of conferences and journals focused on engineering education research.

Teaching Online Engineering: A Systematic Literature Review

Abstract

Globally, online education is becoming increasingly popular because of its flexibility, scalability, and accessibility. Despite these benefits, compared to in-person classes, online education has a comparatively higher dropout rate among students. This research paper focuses on the research on teaching online engineering courses. By understanding the approaches online teachers use to teach, design courses, and challenges faced, we hope to maximize the benefits of learning from online engineering courses. Through exploring teachers' experiences and perspectives, we aim to shed light on the possibilities of online engineering education and its potential to enhance the online engineering education experience. This study aims at answering the following research question 'What are the predominant themes that arise from the research on teaching online engineering asynchronously?'. In this study a systematic literature review on teaching online engineering courses is presented.

A total of 1463 articles were retrieved from seven databases including Web of Science, Google Scholar, IEEE Xplore Library, Science Direct, Engineering Village, EBSCO, and Wiley online library. The following search terms was used to retrieve articles: teaching online engineering, teaching online engineering + challenges, online engineering pedagogy, online teaching practices + engineering, online course design + engineering, online course delivery + engineering, online course assessment + engineering, and instructional design + online engineering. These articles were then screened by abstracts following the nine exclusion criteria and 226 articles made it to the next phase. These 226 articles were then screened by full text and only six articles made it to the final inclusion phase. The themes that emerged from the synthesis of the six articles are improvement of conceptual learning and critical thinking, use of technology for inclusive teaching practices, and enhancement of student interactions and engagement. The findings of this study are timely and relevant as ABET is increasingly accrediting online engineering programs in the United States.

Keywords: online engineering, teaching engineering online, online education

Introduction

Online education is rapidly expanding due to its accessibility, scalability, and flexibility [1-2]. Despite the numerous advantages of online education, there are several challenges that are associated with it. One of the major challenges of online education is student retention, which is relatively lower than in-person face-to-face courses. The factors influencing students' decision to persist in online courses include student course-level persistence, sense of belonging in the community, peer and family support, communication with the instructor, and time management among others [3-5].

Researchers have also predicted online students' course persistence using data describing the students' patterns of interaction with their online course [6-12]. For example, the study by Shelton et al. (2017) [13] identified students at risk of dropping their online course using student–teacher and student–student interaction data, where the frequency of online interactions proved to better indicate student persistence and success than did the length of interactions. And the study by Aguiar et al. (2014) [14] predicted persistence using first-year engineering students' electronic portfolios, extracting information about their course engagement through their reflections about engineering advising, project updates, and engineering exploration throughout the course. Using attributes related to student activities such as assignment skips, assessment performance, and video skips and lags to predict student dropout in online courses, while the study by Halawa et al. (2014) [15] was able to successfully flag 40%–50% of students who dropped out of the course while they were still enrolled. Finally, a study by Morris and Finnegan (2008) [16] student attribute data and student course interaction data to predict students' course-level persistence decisions in separate studies. Each of the studies above underscores the potential to use data related to students' activities in online courses to predict students' persistence decisions.

Additionally, student engagement is another key factor in student success in both online and in-person face-to-face modes of teaching and learning. Student engagement positively influences course-level persistence intentions [6][17-18]. Several researchers have explained student engagement used the course learning management systems (LMS) data include time spent on specific activities online, number of assignment and/or quiz submission, total time spent on the LMS, etc. For instance, the study by Kizilcec et al. (2013) [19] used the students' interaction patterns on their course LMS data to predict their engagement in the course. Additionally, student LMS interaction data was used to predict their retention in online courses [20].

With that background knowledge, it is evident that teaching online courses requires significantly more planning, more effort and time investment compared to in-person face-to-face courses. We would like to acknowledge that we are not looking down upon teaching courses in-person and neither are we hinting at it is easy to teach in-person face-to-face courses. Additionally, we also acknowledge that online education space by itself is too broad and as a part of this research study, we would like to restrict it to online engineering. In this proposed research, we would like to explore the research in teaching online engineering. With ABET increasingly accrediting online engineering programs, the number of online course and program offerings for engineering students has gradually expanded over the last decade [2], however, engineering has been much slower to adopt and investigate the research on online educational format than other disciplines. The outcomes of this study will add to the existing body of knowledge as online engineering is one of the clear pathways for increasing the size and diversity of the engineering workforce.

This research paper aims to focus on the research conducted on online engineering courses with an emphasis of teaching online engineering. By understanding the approaches online teachers use to teach, design courses, and the challenges they face, we hope to maximize the benefits of learning from online engineering courses. Our goal is to gain a comprehensive understanding of what online engineering courses can offer, as we have not yet fully captured their potential benefits in engineering. Through exploring teachers' experiences and perspectives, we aim to shed light on the importance of online engineering education and its potential to enhance the online engineering education experience. Hence, this research study was planned, and I will be conducting a preliminary literature review on teaching online engineering courses.

Methods

This study seeks to answer the overarching research question '*What are the predominant themes that arise from the research on teaching online engineering asynchronously?*'. The following sub research questions were used for exploration, investigation, and categorization of articles under review.

- What were the engineering disciplines used in the sampled articles?
- What were the approaches used by instructors to teach online in the sampled articles?
- What were the frameworks used in the sampled articles?
- What research designs were used in the sampled articles?
- What were the data collection tools used in the sampled articles?
- What were the sampling methods and sample sizes used in the sampled articles?
- What were the data analysis methods used in the sampled articles?

The research framework for this study is referred from Borrego et al. (2014) [21. a.]. This research will be performed in three phases.

1. ***Identification*** – In this phase, the search terms/phrases were used to retrieve articles from different databases. The databases from which the articles were fetched include Web of Science, Google Scholar, IEEE Xplore Library, Science Direct, Engineering Village, EBSCO, and Wiley online library. The articles from all these databases were combined and the duplicate articles will be removed from the pool.

   The following search terms were used to retrieve articles:

   - teaching online engineering
   - teaching online engineering + challenges
   - online engineering pedagogy
   - online teaching practices + engineering
   - online course design + engineering
   - online course delivery + engineering
   - online course assessment + engineering
   - instructional design + online engineering

2. ***Screening*** – In the screening phase, the articles from the identification phase were first screened by abstract to check the applicability and relevance of the articles to our research topic. Additionally, when screening the abstracts, a set of exclusion criteria were used to eliminate the articles that do not relate to the research topic. Next, the articles that remain after the abstract screening were further screened by full texts following the exclusion criteria. At this phase's end, the total number of articles included in the study was narrowed down to 6 articles.

   The exclusion criteria (EC) include,

   - EC1: Articles written in a language other than English
   - EC2: Articles published outside of the years 2014-2023
   - EC3: Work-in-progress publications and short-length papers
   - EC4: Articles that do not focus on online engineering
   - EC5: Articles that focus on synchronous online teaching and learning
   - EC6: Articles that focus solely on Massive Online Open Courses (MOOCs)
   - EC7: Articles that focus solely on transitioning face-to-face courses to online or hybrid courses due to the COVID
   - EC8: Articles that focus solely on blended learning

- EC9: Articles that focus solely on a specific component of a course (an online assignment or online homework) in a non-online course.

The exclusion criteria were intentionally chosen to make sure we retrieve and analyze most recent articles that closely relate to online engineering teaching. For example, we wanted to summarize the findings from the recent research studies published in the last decade to provide a scenario on the recent advancements. Additionally, work-in-progress and short papers were not included as they did not have empirical data to draw conclusions from. We restricted our search only to fully asynchronous online courses to exclude the different online learning contexts (such as MOOCs, hybrid, synchronous online, etc.)

3. ***Synthesis*** **–** The articles that remain after screening by full text will be included in the synthesis phase. In this phase, the final set of articles will be reviewed in detail. During the review process, information from all the articles such as title, year of publication, research questions, research design, sampling methods and sample sizes, data collection, and data analysis techniques among others will be consolidated in a document. This information will be further reviewed to answer the research questions in this study.

4. ***Methodology*** **–** The articles retrieved from each database were grouped in the following way: 7 folders were created for each database. Each folder contained 9 Forms of Excel, each for a different search term. Within any of these Excel sheets, articles were documented based on the publication year. This same process was repeated, but with the folders containing articles after removing duplicates. Once the duplicates were removed, 7 Forms of Excel were created in one folder, each grouping all the articles retrieved for a database across all search terms from 2014–2023 on one sheet. These Forms served as the base for the screening process decisions. Each form contained a field that pertains to the article name, followed by a decision column (accept/reject), then followed by an Exclusion Criteria (EC) column that indicates the exclusion criteria if the decision was to reject. These two columns identified which articles were accepted by abstract screening. Another two columns followed, using the same method, including decision and EC for full-text screening. Through these Forms, the 6 finalist articles were determined. Once the finalist articles were determined, a thorough full-text screening was conducted, and another Form of Excel was created. The Excel Form columns included themes, codes shared under articles identified under each theme, meaning each two articles grouped for a theme had common codes. The following columns included theme description, studies categorized under each theme, research implications, and practice implications. The SLR process and structure/format used in this paper was referred from several existing SLR studies [21-23].

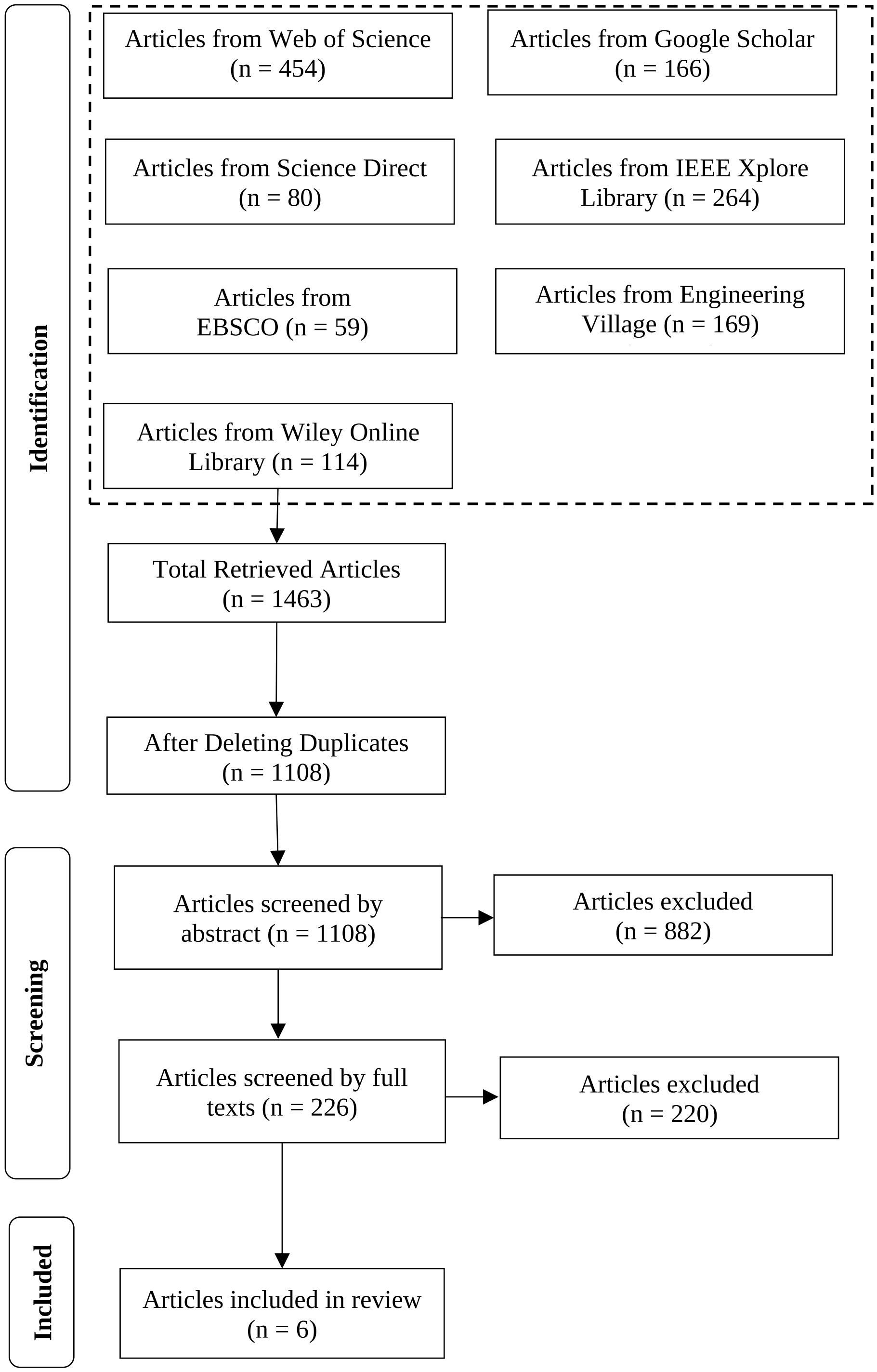

Figure 1. Systematic Literature Review Process

Thematic analysis

In this section, we present predominant themes that emerged from the synthesis of the information from the final six articles. For each theme, a detailed description is provided, and two studies categorized under each theme are explained. In addition, practice implications and research implications are included for each theme.

Theme 1: Improvement of conceptual learning & critical thinking

The articles under this theme employ abstract and innovative methods, including the introduction of various techniques that enhances critical thinking and conceptual learning such as modeling eliciting activities and formative assessments in asynchronous online engineering classrooms [21][24]. These methods involve a significant transformation in teaching procedures and the restructuring of assessments to cultivate critical thinking and enhance conceptual learning for students isolated from face-to-face or synchronous interactions with their educators and peers. The study by Chen et al. (2022) [24] argues that Modeling Eliciting Activities (MEA) is effective in enhancing conceptual learning and critical thinking. It supports this claim by conducting a conceptual learning and design report evaluation tests designed to examine the validity of this hypothesis. The MEA presents questions grounded in real-world scenarios, designed to stimulate thought due to their open-ended nature. This approach allows instructors to effectively evaluate critical thinking and conceptual learning skills within an online engineering classroom. Given the communication challenges inherent in online educational settings, especially the asynchronous settings, such components can be challenging to assess. However, MEA addresses this by offering: a well-structured teaching approach that bridges the gap, ensuring a comprehensive assessment of student capabilities [24]. The other article Chatterjee et al. (2016) [21] contends that an intentional design of formative assessments to include questions that cultivate critical thinking is essential in an asynchronous online engineering setting where elements that stimulate critical thinking can be less present and need to be more emphasized. To do so, instructors can be intentional about the type of questions asked whether open or close ended for example. Additionally, they can provide feedback in a timely manner and put effort to cover content that students struggle with according to the collected feedback [21].

Study 1

The study by Chen et al. (2022) [24] examines the integration of Modeling Eliciting Activities (MEA) in the online engineering classroom. This approach enhances various skills, including conceptual learning and professional skills, among which critical thinking is enlisted as a professional skill. There are six principles of MEA: modeling, reality, self-assessment, documentation, generalization, and prototype [24]. Three of them, namely modeling, generalization, and prototype, contribute significantly to enhancing critical thinking and conceptual learning. MEA focuses on assigning students' tasks derived from real-world examples, enabling them to develop a sound understanding of theory and its application. This study has three hypotheses combined to sum up as MEA online teaching is better than teacher-centered online teaching in conceptual thinking, professional skills, and interaction enhancement [24]. There were five tests designed to explore these hypotheses. The tests were designed and distributed to two groups experimental group and a control group for comparison. Overall, the results of the conceptual learning test showed that MEA online teaching shows better results than conventional teacher-centered online teaching, and a similar outcome was shown in the design report evaluation test which evaluates critical thinking. The design report evaluation test reported positive results for MEA online courses [24].

Study 2

Another study by Chatterjee et al. (2016) [21] investigates the design of an asynchronous online engineering classroom, focusing specifically on cognitive radio networks. A prominent feature of the course design is the emphasis on various assessment methods, including asynchronous online discussions, virtual labs, open-ended module assignments, and a final project. Central to this approach is the integration of feedback mechanisms within these assessment methods [21]. The educational strategies in this study stray away from the traditional assessment approaches such as sit-in proctored exams and multiple-choice questions [21]. This shift away from conventional assessment methods aims to enhance critical thinking skills in students through innovative assessment practices. The assessments are strategically designed to correlate with the course objectives, focusing on evaluating students' understanding in a comprehensive manner by seeking to foster meaningful interactions between students and their peers, as well as with instructors. The assessments in this study included open-ended questions that incorporated real-world scenarios, which encourages students to employ their analytical skills in formulating well-reasoned answers. The course outcomes are structured around three core objectives: to analyze, understand, and evaluate the complex aspects of cognitive radio [21]. This structure is designed to enhance students' abilities to comprehend and articulate the course material, thereby improving their critical thinking skills. The open-ended nature of the questions encouraged students to offer their perspectives and suggest solutions, requiring them to engage in creative and critical thinking, enhancing their ability to critique and evaluate solutions [21].

Research Implications

In this section, the research implications for the first theme are explained. The future research should consider the challenges associated with incorporating theoretical content into MEA-based instruction, thereby broadening the scope of investigation to encompass both practical and theoretical aspects of online learning MEA learning [24]. Additionally, a study could be conducted by including students at different educational levels, such as postgraduate education. This expansion would contribute to a more comprehensive understanding of the implications and effectiveness of MEA in diverse educational settings. One more consideration would be to consider students from different engineering disciplines and therefore different socioeconomic backgrounds, acknowledging the potential impact of economic class on the quality of education [24]. Finally, future research endeavors could also involve ongoing refinement of assessments based on feedback collected from students throughout the semester, encompassing the beginning, middle, and end of the academic term to enhance students' conceptual learning and critical thinking [21].

Practice Implications

The incorporation of MEA fosters meaningful interactions within the classroom. Instructors stand to gain valuable insights by leveraging the structure and principles of MEA. This could manifest through an introduction of problems via step-by-step planning, offering students real-world scenarios to apply their acquired knowledge. For instance, instructors could derive considerable benefits from embracing the 'modeling principle'—implementing a solution construction and explanation-oriented approach [24]. Furthermore, instructors can capitalize on the 'generalization principle' by requiring solutions that transcend specific cases and instead demonstrate a broader applicability [24]. Additionally, the 'prototype principle' encourages the adoption of simple and straightforward solutions. By implementing or emulating these principles, instructors can enhance critical thinking and conceptual learning in their online teaching approaches [24]. The instructors can also use different assessment methods to help students learn different skills. Instructors can incorporate open-ended, and real-world-focused assessments that align closely with testing students' understanding of the course content and learning objectives.

Additionally, delivering effective feedback promptly after assessments is crucial. Through timely feedback, instructors can pinpoint areas where students underperform, allowing them to allocate more time to enhance knowledge in those specific areas [21].

Theme 2: Use of Technology for Inclusive Teaching Practices

The articles under this theme use technological advancements to employ inclusivity in asynchronous online teaching practices. Given the different nature of the articles inclusivity here has a broad definition. The way inclusivity is employed in the study by Avanzato (2017) [25] embracing technology inclusivity in the sense that students receive technical training to learn how to use the Terf tool, additionally engagement and collaboration are established and improved in the virtual environment while using Terf. Moreover, Terf enables access to geographically distant users and enables students from different classes and levels in college to connect. Such feature that not available in traditional online engineering settings and or in person taught classes and its use can be capitalized in asynchronous online engineering classrooms [25]. In another study by Batanero, et al. (2019) [26] inclusivity was approached by providing adaptable content to students with differing capabilities referring to deaf, blind, and blind-deaf students who participated in the study to assess the effectiveness of the adapted Moodle platform [26]. In this context adapting a platform means providing users with content that suits their needs [26]. This inclusivity practice in the study enabled students to view content that were not able to access previously [26]. Instructors in the realm of online engineering, especially asynchronous online engineering, could find these technologies particularly advantageous. They offer a way for instructors to become more attuned to their students' needs, in an environment where both instructors and classmates are physically distant.

Study 1

The study by Avanzato (2017) [25] delves into the application of virtual reality technology, specifically Terf virtual world technology. Turf is an example of creating an inclusive technological environment that provides users with accessibility and connectiveness to peers and instructors. In the sense that technology accessibility refers to the use of tools by people with a variety of limitations and abilities. It is crucial to create inclusive technology cultures that promote participation, teamwork, and a sense of belonging to represent a diverse workforce and provide value [27]. The utilization of Terf virtual world technology granted students the ability to collaborate in virtual teams, all while personalizing their 3D experience through customized avatars, and facilitated communication within teams by enabling screen sharing capabilities [25]. fostering a sense of identity and community among the students featuring technological inclusivity.

Additionally, students gained proficiency in navigating this tool through two dedicated orientations. These orientations included exercises such as placing sticky notes with student information, preparing students to use this technique in subsequent assignments and enhancing their overall Terf proficiency featuring technology inclusivity once again [25]. Furthermore, students had the freedom to move between stations and join discussions with other groups during presentations of assignments. Moreover, Terf expanded inclusivity to a new horizon by enabling students from various levels and classes to meet and interact, which is atypical in other engineering teaching settings including the online engineering classroom and in person classes. Even more, one student even commented, 'You felt more a part of the course than your 'normal' online class, better interaction between students and the teacher [25]. In the study's findings, it was noted that the academic achievement level using Terf was like the course taught without it; however, the engagement level was significantly enhanced [25].

Study 2

The study by Batanero, et al., 2019 [26] explores the restructuring of the Moodle platform to accommodate the needs of engineering students who are blind, deaf, or deaf-blind, often referred to as students with different capacities. The main goal is to develop a platform that can adjust Learning Objects (LOs), which are defined as digital educational materials that are reusable and self-contained and have a distinct learning aim, to the needs of the user [26]. This platform will be tailored to deliver educational content that accommodates students' different capacities. Furthermore, this article directs its attention to e-learning, which is a learning method that encompasses accessibility from anywhere in the world and the convenience of accessing content whenever needed for reference [26]. Given that the platform is virtual, it provides flexibility that can improve accessibility. However, students with different capacities often encounter technical challenges when utilizing such platforms. Therefore, this study seeks to evaluate the effectiveness of the approach implemented.

The study emphasizes that while some content is accessible online for students with different capacities, it is still insufficient and only offers a partial level of accessibility because of the platforms ongoing technological updates [26]. For example, although the Moodle platform has many customizable options that improve accessibility, full accessibility is still not achieved. Hence, the focus of this study is on how the Moodle platform adapts digital content to provide full accessibility. The study's unique contribution lies in its focus on how the Moodle platform adapts digital content to bridge this gap, particularly in the specialized realms of computer engineering and telecommunications.

Students' performance was compared before and after utilizing the modified Moodle platform as part of the study. The participants were students who were blind, deaf, or deaf-blind; most of them were between the ages of thirty and fifty [26]. The participants were taught how to use the platform and received help with technical issues. Repeated testing was conducted to gauge consistency in performance. The findings showed a considerable improvement in learning performance for all three groups: deaf (46.25%), blind (45%), and deaf-blind (87.5%) [26]. The number of deaf-blind participants was only three students, which made it difficult to generalize the data [26]. By providing content that is accessible to students with different capacities, they were better equipped to answer questions that required vision, hearing, or both thanks to the adaptation of the questions presented to them [26].

Research Implications

In this section, the research implications for the second theme are explained. Future studies should aim to broaden the participant base, encompassing a larger cohort of students both within the classroom setting and the research framework. A focus on students with prior exposure to online learning environments would facilitate a sound understanding of the influence of 3D virtual tools on engagement within the online classroom context. Moreover, there is an opportunity to delve deeper into the multifaceted features of Terf, including its administrative management capabilities, the Python API, comprehensive analytics for monitoring student engagement, and the customization of 3D environments, and how these can be seamlessly integrated into the online engineering classroom. Extending the application of Terf across various online engineering courses is worthy of exploration, considering the vast spectrum of course natures and contents within the engineering discipline. Enhancing the quality of future research endeavors would also benefit from the implementation of more detailed student orientations, crafted based on student feedback. Furthermore, addressing the concerns pertaining to voice experienced by students while using Terf should be a focus for further examination [25] On the other hand, future research for the study by Batanero, et al., (2019) [24] Subsequent research entails conducting trials with more extensive samples to establish the generalizability of the findings [26]. Additionally, future studies could study the extension of the use of the Moodle adapted platform into fields that are challenging and less available for students with different capacities including Linguistics and Mathematics [26].

Practice Implications

Instructors can improve their classes by using 3D virtual reality tools. To start, teachers should make sure students understand how to use these tools by giving them the right information and practice. To encourage students to use these tools more, teachers can offer extra points for using them well or for taking part in extra virtual activities. Also, it is important for teachers to ask students what they think about using these tools and how easy or hard they are to use. Listening to students and fixing any issues they have can make the class more interesting and inclusive for everyone [25].

Similarly, instructors can enhance inclusivity and content comprehension in their classrooms by incorporating adapted platforms into their curriculum. This approach requires them to first understand the diverse needs of their students and to coordinate with the university to secure the necessary platform licenses, ensuring all students have equitable access based on available funding. The adapted Moodle platform, for instance, is particularly beneficial for students who are deaf or blind. Instructors can also stay informed about the latest research on these specialized learning platforms and their application in online engineering classrooms. By utilizing these adaptive tools, instructors can significantly improve the learning experience, addressing the unique challenges of online engineering and the complexities of the digital environment, thereby meeting the varied needs of their students more effectively [25].

Theme 3: Enhancement of student Interactions and engagement

The articles under this theme concentrate on designing classrooms and methods to boost student interactions and engagement in asynchronous online engineering courses. They delve into the concepts of engagement and interactions from different perspectives. The article by Sarder (2014) [28] discusses the development of a Multi-tiered Online Delivery (MOD) system, crafted from the ground up using Java. This MOD system is part of the Teaching and Learning Based on Engagement (EBLT) approach, serving as the pedagogical component, while the course design meets the specified preconditions [28]. On the other hand, the study by Santiago & Abioye (2014) [30] investigates the design of an online computer programming course for first-year students. It aims to enhance interactions between students, between students and educators, and between students and resources. This is achieved through technological means such as online office hours and the creation of a blog where students can post comments and questions. The study also promotes teamwork and the assignment of homework and projects, based on the premise that students in an online classroom need to exert more effort and take charge of their performance [30]. Although this approach of placing more responsibility on the students is not conducive to customizing assignments and engaging students, the study was conducted in 2014. Instructors can adopt strategies to design their courses in ways that enhance interactions and engagement across several levels and components. As previously discussed, there are several types of interactions to fortify in an online engineering classroom, including those between students, between students and teachers, and between students and materials. Additionally, educators can enhance their technological proficiency by familiarizing themselves with educational technology tools. They can also engage in self-development courses aimed at improving their teaching techniques in an online environment, as discussed in the study by [28].

Study 1

The study by Sarder (2014) examines various strategies to enhance interaction and participation in the University of Southern Mississippi's (USM) online engineering courses, specifically within the Industrial Engineering Technology (IET) program, which has been fully transitioned to an online format. This research adopts the Teaching and Learning Based on Engagement (EBLT) approach, focusing on two main pillars to bolster student engagement: preconditions and pedagogy. Preconditions refer to a set of criteria that must be fulfilled for teaching to be effective, while pedagogy involves the instructional methods that must be followed [28]. Central to this approach is the emphasis on enhancing interactions between students and teachers, as well as between students and the course material. To facilitate this, an online Lecture Management System (LMS) was developed from scratch using Java. This LMS incorporates a Multi-tiered Online Delivery (MOD) system with three key tiers: Lecture Recording, Offline Lecture Splicing, and Student Interaction. The first tier breaks down lectures into manageable segments, capturing moments when students pose questions during the recording. The second tier focuses on identifying quiz questions for each segment and extracting recorded interactions into separate media files for each student-teacher interaction. The final tier engages students with the content by preventing fast-forwarding of segments until quiz questions are correctly answered. After completing a segment with a satisfactory score, the fast-forwarding feature is enabled. When all segments are completed, the lecture becomes fully accessible with fast-forwarding, and the questions asked during the lecture are made available. Thus, the first section of the EBLT is designed and successfully implemented. The second part focuses on preconditions required for setting up an engaging class environment. Fundamental among these is the establishment of learning relationships between students and teachers, underlining the belief that students are more likely to exert effort in environments where they perceive their teachers as engaged and caring. Additionally, a well-organized and maintained learning space is quite significant. Such an environment should be structured, easy to navigate, and adhere to a clear schedule. Furthermore, implementing a system of rewards and incentives is crucial for enhancing motivation. When applied thoughtfully, these strategies encourage a deeper sense of intrinsic motivation and greater engagement in learning. Emphasizing proper procedures and practicing them until they become habitual is another vital strategy for increasing engagement. Lastly, possessing foundational skills is critical; without the basic knowledge necessary for active participation and success in the class, students are more likely to be less engaged and more willing to withdraw from an online course [28]. It's important to note that while this strategy was devised for the study, the findings indicate that the MOD technique worked well, but they are neither definitive nor easily generalized [28].

Study 2

The study by Santiago & Abioye (2014) [30] delves into the enhancement of three types of interactions: between students, between students and instructors, and between students and course materials in a first-year online computer programming course, which is a requirement for many engineering disciplines [30]. The course is structured into 10 modules, with learning objectives clearly communicated at the beginning of each to address research findings indicating that students tend to underperform in online classes when they lack a clear understanding of the learning objectives. This approach aims to improve comprehension and performance by ensuring that students are aware of what is expected from them right from the start. A noteworthy aspect of this study is the decision to offer the final exam in person. Because the course was conducted online throughout the semester, this element did not lead to its exclusion based on our criteria, as the in-person final exam was not deemed to influence the overall online teaching methodology. The study also highlights the intentional basis for increased interactivity in the online computer engineering classroom. The enhancement of interactions between students and instructors was facilitated through regular emails containing notifications about due dates and online office hours, in addition to providing solutions to assignments. Office hours, available daily and with the encouraged use of cameras and microphones, played a crucial role in enhancing interactions between students and instructors [29]. Interactions among students were fostered through intentionally assigned team members by the instructor, ensuring matching availability to establish agreed meeting times. Moreover, the use of blogs to discuss assignments and the effectiveness of teamwork, particularly after the intentional team assignments, further boosted interactivity [30]. Finally, interactions between students and course materials were enhanced through assigning homework, projects, and quizzes to keep students engaged with the content [30].

Research Implications

In this section, the research implications of the third theme are discussed. Future research should consider completing the project described in the study by Sarder, (2014) [28]. While this research study presents comprehensive findings, it opens the door for a thorough assessment of technology's impact on instructors and students in online engineering classrooms through the project's implementation in universities and community colleges. Fully completing and implementing this project would yield more definitive results regarding student engagement in online engineering classrooms using the EBLT and MOD approaches. Furthermore, it would provide instructors with effective means to enhance interactions within their classrooms [28]. On the other hand, future research for the study by Santiago & Abioye (2014) [29] could emphasize the use of innovative technology that fosters a sense of presence during online office hours. Additionally, future studies could offer students information on the status of their peers within the platforms they are using, including whether they are online and their level of achievement within the class. This could promote a sense of positive competition among students, further enhancing their interactions [29].

Practice Implications

Instructors can derive invaluable insights from the study by Sarder (2014) [28]. This research not only investigates the effects of EBLT and MOD approaches on student engagement and interactions within the classroom, but it also focuses on creating a program named 'Educating Educators.' This initiative is based on the results derived from the research, aiming to better equip instructors for teaching in online engineering environments. It emphasizes capitalizing on the methods that have proven most effective for online teaching. Given that online engineering education is a relatively new field, with effective teaching approaches not yet fully explored, this program seeks to address this gap by offering strategic insights and tools for educators. Instructors can benefit from the preconditions defined in the study. For instance, they could enhance the learning environment by adhering to a clear plan and structure for the course, while avoiding changes that could disrupt the course flow and pose challenges to students [28]. Regarding incentive and reward systems, instructors can wisely set up mechanisms that reward students based on their performance, without being excessive [28]. Another valuable precondition involves the recognition and formation of classroom routines through the introduction and repetition of certain practices to form habits [28]. Additionally, instructors could benefit from the MOD approach developed and implemented in the study, as it discourages passive fast-forwarding of lecture content, thereby enforcing positive student-content interaction (Sarder, 2016).

On the other hand, instructors could benefit from the study by Santiago & Abioye (2014) [29] by conducting daily online office hours and being readily available to answer questions via email, thereby providing students with effective and efficient means of feedback. Additionally, they could facilitate teamwork in their classrooms by assigning tasks based on the matching availability of students. Furthermore, they could encourage students to provide feedback on their teammates' work, thus holding them accountable and responsible for maintaining high-quality work and attending meetings. Moreover, allowing for the resubmission of homework could give students a better opportunity to re-engage with the content and improve their performance, while also enabling instructors to adapt based on student feedback [29].

Conclusions

This study is centered around instructing online engineering courses and comprehending the methodologies employed by online educators in course design and the obstacles they encounter. The research question addressed in this study is, ‘What are the predominant themes that arise from the research on teaching online engineering asynchronously?’ To answer this question, we conducted a systematic literature review (SLR) that encompassed seven databases, and eight search terms. The search terms were designed in a way that they give us specific results and narrow down our results of articles to the field of teaching online engineering education. The initial number of articles retrieved was 1463 articles, after removing duplicates 1108 were retrieved. An exclusion criterion was developed and followed through the abstract screening of articles, 882 articles were excluded, 226 articles were screened by full text, and 219 were excluded. The remaining six articles were thoroughly considered and reviewed. Despite the enormous number of articles initially collected only six emerged as finalists. The small number of articles selected can be attributed to several factors. Firstly, we applied a strict set of search terms and exclusion criteria, which, while ensuring the relevance and quality of the articles, limited the pool of potential candidates. Additionally, access issues played a significant role; for some articles that passed our initial abstract screening, we were unable to obtain the full papers, further narrowing our selection. Lastly, it's worth noting that the field of strictly asynchronous online engineering education is still emerging, with relatively few studies conducted to date. This scarcity of research has inevitably influenced the volume of articles available for consideration in our study. This could also be viewed as a strength as it emphasizes the need for further research in asynchronous online engineering and adds to the body of knowledge in this area.

In-depth analysis of the six finalist articles revealed five main themes: improvement of conceptual learning and critical thinking, use of technology for inclusive teaching practices, enhancement of student interactions and engagement, instructors' pedagogical approach and course design, and challenges of course delivery. However, the methodology for theme write-ups, necessitating a unique explanation of two exemplar studies, and the constraint of having only six finalist articles, necessitated narrowing the themes to three: improvement of conceptual learning and critical thinking, use of technology for inclusive teaching practices, and enhancement of student interactions and engagement.

The limitations that emerged are that only articles written in English were included in the study, this means that there could have been research conducted on completely asynchronous in other languages that could not have been covered by this study. Future research could aim to explore articles in other languages, depending on the linguistic capabilities and background of the researchers. Additionally, future studies could strategically utilize search terms to capture a broader range of articles on the topic, as the current study incorporated only six articles in its final phase. A comparison of research on synchronous versus asynchronous online teaching could yield critical insights for instructors looking to enhance their online teaching methodologies. Another limitation was the inaccessibility of some articles that appeared promising for full-text screening after passing the abstract screening phase, due to the lack of access to the publishing journals and websites.

Acknowledgment

This project was supported by the Provost's Summer Undergraduate Research and Creative Activities (UReCA) Fellowship. Its contents, including findings, conclusions, opinions, and recommendations, are solely attributed to the author(s) and do not necessarily represent the views of the Provost's Office

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