Jurnal Dinamika Vokasional Teknik Mesin
Vol. 10, No. 1, April 2025, pp. 01-16
https://journal.uny.ac.id/index.php/dynamika/issue/view/79538
ISSN: 2548-7590, DOI: 10.21831/dinamika.v10i1.79538

Digital Literacy Skills of Mechanical Engineering Education Lecturers: A Systematic Literature Review in the Context of Industry 4.0

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Article Info

Article history:

Received Nov 29, 2024
Revised Mar 19, 2025
Accepted Mar 25, 2025
Published Apr 30, 2025

Keywords:

Digital Literacy
Industry 4.0
Lecture
Mechanical Engineering
Systematic Literature Review
Training

ABSTRACT

The main issue is the gap in digital literacy competence among mechanical engineering education lecturers due to the lack of adequate training, support, and facilities from the institution. This research used a systematic literature review approach to identify the gaps in digital literacy among mechanical engineering education lecturers. A systematic literature review was conducted, starting with exploration, evaluation, and presentation of data from previous studies that discuss digital literacy competence for lecturers, especially in the context of mechanical engineering education. A total of 100 international articles published between 2018 and 2024 were reviewed based on keywords and research findings. After the review, 66 relevant international articles were identified and can be used as the foundation for this research. The results of the study show that digital literacy competencies for lecturers in mechanical engineering education are crucial in improving the quality of teaching and student competencies to face the challenges of Industry 4.0. Intensive and ongoing training programs can enhance lecturers' abilities to master technology, with the prospects of this research focusing on cybersecurity, digital ethics, and more structured training programs to support innovative mechanical engineering education, thus meeting the demands of the ever-evolving job market. This study contributes to the existing literature by providing a comprehensive synthesis of digital literacy challenges and potential solutions in mechanical engineering education, emphasizing the urgent need for structured and targeted training programs. The novelty of this research lies in its focus on identifying specific gaps in digital competencies within this discipline, highlighting key areas such as cybersecurity and digital ethics, which have been underexplored in previous studies

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INTRODUCTION

In facing the challenges of Industry 4.0, digital literacy becomes a crucial competence that lecturers, including those in mechanical engineering education (Yazon et al., 2019), (Z. J. Liu et al., 2020). Digital literacy enables lecturers to effectively integrate technology into teaching, research, and professional development (Kateryna et al., 2020), (Smolyaninova & Bezyzvestnykh, 2019). Lecturers

can use digital technology to develop teaching methods that align with industry needs, such as data-driven analysis, engineering simulations, and 3D modeling (Alias et al., 2018), (Fuertes et al., 2021). However, despite its importance, digital literacy remains a challenge for many lecturers, particularly in mechanical engineering education, where mastering specialized software and complex digital applications is often required (Hernandez-de-Menendez et al., 2020), (Ismail & Hassan, 2019).

The primary issue identified in this study is the digital literacy gap among lecturers in mechanical engineering education, which is caused by a lack of training, institutional support, and access to relevant facilities (Caratozzolo et al., 2021), (Kovalchuk et al., 2022). Many lecturers, particularly those with longer teaching experience, are not fully aware of the significance of digital literacy as an integral part of their professional competencies (Spante et al., 2018a), (Caena & Redecker, 2019). Another significant challenge is the technological proficiency disparity between senior and junior lecturers, where senior lecturers tend to be less familiar with digital technology compared to their younger counterparts (Iivari et al., 2020). This disparity hinders the creation of an adaptive, technology-based learning environment in mechanical engineering education (Dangi et al., 2022), (Dumford & Miller, 2018).

Several studies suggest that lecturers with a high level of digital literacy positively impact the quality of teaching and student competence. For instance, research conducted by (Mardiana, 2024) demonstrates that lecturers with strong digital literacy skills can create innovative learning environments by effectively utilizing online platforms. Similarly, (Abbas et al., 2019) found a direct correlation between lecturers' digital literacy and students' academic achievement. Moreover, (Mujtahid et al., 2021) highlighted that lecturers' ability to establish conducive learning environments is significantly influenced by their level of digital literacy mastery. While these studies emphasize the importance of digital literacy, most existing literature focuses on students or lecturers in general, without specifically addressing mechanical engineering education. Research explicitly examining digital literacy competencies among mechanical engineering education lecturers is still limited, despite the field’s high demand for advanced technological integration. Existing studies primarily explore general pedagogical technology use, whereas this research aims to fill the gap by investigating digital literacy competencies specifically within the context of mechanical engineering education. The specific research questions are: (1) What is the digital literacy competency for lecturers in mechanical engineering education? (2) How is digital media used in mechanical engineering education? (3) What is the impact of digital literacy on the learning process?

A systematic literature review approach is employed to identify the current state of digital literacy among mechanical engineering education lecturers and the influencing factors. This method systematically explores prior research (Khoo-Lattimore et al., 2019) to provide a comprehensive analysis of existing gaps and areas for improvement. To address these gaps, this research proposes the implementation of structured and continuous training programs to enhance the digital competencies of

mechanical engineering education lecturers. These programs could include specialized training on mechanical engineering applications, hands-on workshops for integrating technology into teaching, and seminars on emerging educational technologies. A more structured, needs-based approach will enable lecturers to integrate technology more effectively into their teaching activities.

The novelty of this research lies in its specific focus on the digital literacy competencies of lecturers in mechanical engineering education, an area that has been largely overlooked in previous studies. Unlike prior research that primarily addresses general technological competencies, this study explores multiple dimensions, including digital ethics, cybersecurity, and the ability to adapt to rapidly evolving technologies. By filling this research gap, the findings of this study will serve as a valuable reference for technical education institutions to design targeted faculty development programs, ultimately enhancing the quality of technical education in response to Industry 4.0 demands.

METHOD

The approach used in this research is a systematic literature review model. This research follows a structured process involving theme identification, literature selection, evaluation, analysis, and data interpretation. In conducting a systematic literature review, the researcher explores, evaluates, and interprets previous research findings that are relevant and can serve as support for the research theme (Fernández-Batanero et al., 2022). This study specifically focuses on digital literacy competencies among lecturers in mechanical engineering education, which remains an underexplored area in existing literature. This literature review is conducted with the aim of identifying recent literature that can serve as a foundation for research related to digital literacy competencies for lecturers, drawing from sources that have been previously examined (Spante et al., 2018b). Figure 1 illustrates the research flow conducted, from the identification of theme into the data interpretation.

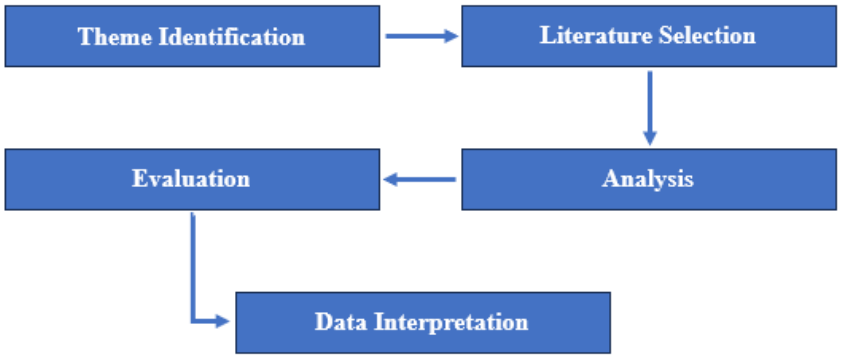

Figure 1. Research Flow

The research process began with theme identification, specifically focusing on the digital literacy competencies of lecturers in mechanical engineering education. A literature selection was then conducted using Google Scholar, the Directory of Open Access Journals, and ScienceDirect, retrieving

articles based on relevant keywords. The analysis process applied strict inclusion criteria, which required that articles be published in international journals or proceedings, written in English, and published between 2018 and 2024, with a clear focus on digital literacy competencies for lecturers in mechanical engineering education. The evaluation phase initially collected 100 international articles, which were then filtered based on relevance, resulting in 66 selected articles for further analysis. Finally, in the data interpretation stage, the extracted information was organized into tables, analyzed systematically, and synthesized to draw key conclusions regarding the current state, challenges, and potential improvements in digital literacy competencies among lecturers in mechanical engineering education.

The selected articles were analyzed using content analysis and thematic analysis. Content analysis was employed to systematically categorize findings, focusing on patterns related to digital literacy competencies in mechanical engineering education. Thematic analysis was used to identify recurring themes, trends, and research gaps across the selected studies. The analysis process involved coding key aspects, summarizing key findings, and presenting the data using tables for better visualization. The findings from this systematic review provide an in-depth understanding of digital literacy competencies among mechanical engineering education lecturers and highlight areas requiring further development.

RESULTS AND DISCUSSION

This results section outlines the findings from the synthesis data evaluation, aiming to map the initial visualization of the interconnections between articles. This mapping is based on the year of publication, research methodology, and relevance to the three research questions previously outlined: digital literacy competence among technical education lecturers (Question 1/Q1), the use of digital media in learning (Question 2/Q2), and the impact of digital literacy on the learning process (Question 3/Q3). The presentation of the evaluation results from the data synthesis can be seen in Table 1.

Table 1. Findings from the articles based on keywords relevant to the research questions

No	Year	Methodology	Question	No	Year	Methodology	Question
1	2018	Survey Research	Q1	34	2021	Systematic Review	Q2
2	2019	Quantitative	Q1	35	2022	Systematic Review	Q2
3	2021	Case Study	Q1	36	2019	Literature Review	Q2
4	2019	Qualitative	Q1	37	2023	Survey Research	Q2
5	2020	Survey Research	Q1	38	2018	Literature Review	Q2
6	2018	Survey Research	Q1	39	2019	Experiment Design	Q2
7	2019	Quantitative	Q1	40	2022	Qualitative	Q2
8	2020	Experiment Design	Q1	41	2020	Experiment Design	Q2
9	2020	Qualitative	Q1	42	2020	Mixed Method	Q2
10	2018	Mixed Method	Q1	43	2020	Survey Research	Q2
11	2022	Literature Review	Q1	44	2019	Literature Review	Q3
12	2022	Qualitative	Q1	45	2019	Literature Review	Q3
13	2021	Case Study	Q1	46	2019	Survey	Q3
14	2024	Qualitative	Q1	47	2024	Qualitative	Q3
15	2022	Qualitative	Q1	48	2022	Quantitative Survey	Q3
16	2021	Quantitative	Q1	49	2021	Quantitative Survey	Q3
17	2018	Case Study	Q1	50	2021	Quantitative Survey	Q3
18	2020	Qualitative	Q1	51	2020	Qualitative	Q3
19	2021	Survey Research	Q1	52	2021	Survey Research	Q3
20	2022	Qualitative	Q1	53	2020	Survey Research	Q3
21	2024	Survey Research	Q1	54	2021	Systematic Review	Q3
22	2021	Qualitative	Q1	55	2021	Literature Review	Q3
23	2021	Survey Research	Q1	56	2022	Quantitative	Q3
24	2021	Quantitative	Q2	57	2021	Quantitative	Q3
25	2019	Literature Review	Q2	58	2020	Literature Review	Q3
26	2019	Qualitative	Q2	59	2020	Experiment Design	Q3
27	2023	Systematic Review	Q2	60	2020	Qualitative	Q3
28	2019	Experiment Design	Q2	61	2023	Literature Review	Q3
29	2021	Survey Reseasch	Q2	62	2023	Literature Review	Q3
30	2022	Literature Review	Q2	63	2021	Mixed Method	Q3
31	2021	Qualitative	Q2	64	2018	Quantitative Survey	Q3
32	2018	Systematic Review	Q2	65	2019	Case Study	Q3
33	2019	Survey Research	Q2	66	2021	Quantitative Survey	Q3

Figure 2 shows the distribution of publication years for each research question

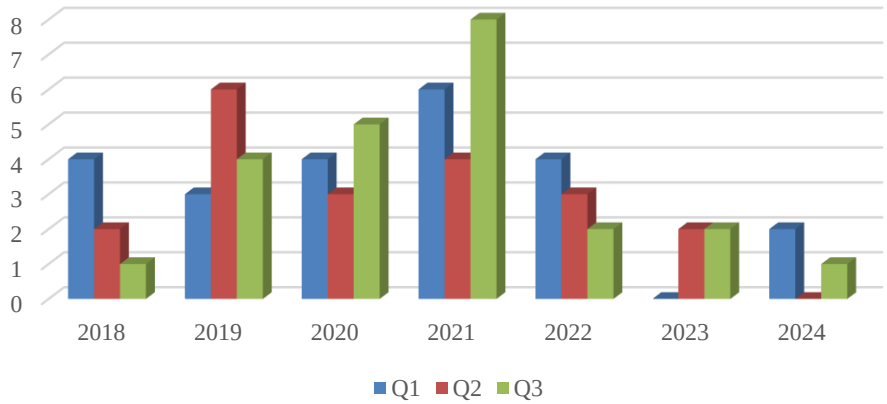

Figure 2. Distribution of Publication Years for Each Research Question

Figure 3 shows the distribution of research methodologies in the articles used as sources for the literature review.

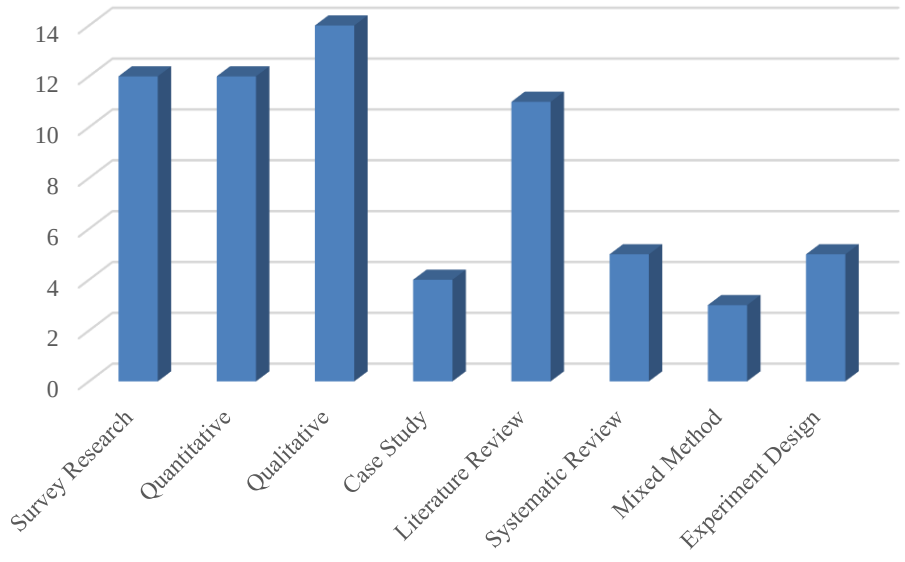

Figure 3. Distribution of Research Methodologies in the Articles

Figure 2 illustrates the distribution of publication years for references used to answer research questions Q1, Q2, and Q3. The data show a significant increase in relevant publications from 2018 to 2021, peaking in 2021, particularly for Q3. After 2021, the number of publications gradually declines, with fewer references in 2023 and 2024. This trend suggests that most relevant studies were conducted between 2019 and 2022, indicating a strong research focus during these years.

Figure 3 illustrates the distribution of research methodologies used in the referenced articles. It shows that Qualitative Research and Survey Research are the most frequently employed methods, followed by Systematic Reviews. Meanwhile, Case Studies, Literature Reviews, Mixed Methods, and Experimental Designs appear less frequently. This distribution indicates a strong reliance on qualitative approaches and surveys in the reviewed literature.

Digital Literacy Competence for Mechanical Engineering Education Lecturers (Q1)

Based on the literature analysis, it can be observed that mechanical engineering education lecturers generally have a basic understanding of the use of digital technology (Soyemi et al., 2018). This level of proficiency is also influenced by the constantly evolving technology, which forces lecturers to continuously keep up with the times (Omosekejimi et al., 2019). The majority of lecturers are able to operate software such as Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), and other similar engineering simulation applications (Sola-Guirado et al., 2022). In addition to the ability to operate such applications, the ability to use online learning platforms such as Learning Management Systems (LMS) and others is also crucial, as these skills have been widely adopted (Sarker et al., 2019).

A lecturer's digital literacy competence is essential to support the teaching and learning process in the digital era (Z.-J. Liu et al., 2020). The competence referred to is the ability to use technology in designing digital-based learning materials, such as interactive modules, educational videos, and

simulation-based tutorials. By mastering technology well, lecturers can easily create a more engaging learning experience and environment for students, enabling them to be more active in the learning process (Holbrey, 2020). However, the level of lecturers' proficiency with this technology varies, depending on their educational background, technological experience, and individual willingness to continuously develop their digital skills and capabilities (Farjon et al., 2019). Lecturers with a strong technological background and more experience using technology tend to find it easier to master and apply technology in the teaching and learning process (Rapanta et al., 2020). Meanwhile, lecturers who are less familiar with technology and rarely use it will find it challenging to apply technology in the teaching process. Therefore, additional training is needed to help them use technology efficiently (Seale et al., 2021).

One indicator of a lecturer's digital literacy is the ability to identify and solve problems related to the use of technology in the teaching and learning process (Techataweewan & Prasertsin, 2018). Lecturers are able to use and apply technology according to the learning needs of students, such as utilizing specific applications to support certain courses, which in turn makes students more engaged in the learning activities and helps alleviate their boredom (Vu, 2022). One example of this is the use of Autodesk Inventor application in Product Design courses, which makes it easier for students to design the products they envision (Qosimov et al., 2022). The use of the Ansys application in teaching analysis and engineering simulations is also implemented to engage students more effectively in the process of structural calculations and construction in the field of mechanical engineering (Srinivasan & Centea, 2021).

Lecturers in mechanical engineering education face many challenges in adapting to the rapid advancement of technology, especially when it comes to integrating new technologies into the learning process (Sidhu et al., 2024). Younger lecturers tend to be more ready and adaptable in using and applying technology in teaching because they are accustomed to being in environments filled with technology (Haleem et al., 2022), such as using computer-based design or simulation software in teaching. On the other hand, senior lecturers find it more challenging to integrate technology into teaching due to the complexity of technology, limited access to training, and their comfort with conventional teaching methods (Zalat et al., 2021). However, in such conditions, senior lecturers can bring valuable experience and a deep understanding of learning concepts, complementing the innovations introduced by younger lecturers (Dyment et al., 2018). With this collaboration, and of course supported by the institution through training programs and the upgrading of facilities, all lecturers can create innovative and interactive learning experiences to prepare students to face the challenges of an increasingly modern workforce (Ahmad, 2019).

The digital competence of mechanical engineering education lecturers consists of several key elements: technical skills, critical thinking, digital ethics, and innovation (Neves et al., 2021). These technical skills refer to the lecturers' ability to utilize both hardware and software in the teaching and

learning process of engineering (Laleye, 2022). Critical thinking refers to how lecturers evaluate the effectiveness of digital tools and technologies used in the learning process (Dang et al., 2024). Digital ethics refers to how lecturers responsibly use technology in the learning process, adhering to applicable regulations and guidelines (García-Peñalvo, 2021). Innovation refers to the ability of lecturers to update and implement new learning models by leveraging the latest technologies to create an effective and engaging learning environment for students (Yusriadi, 2021).

The Use of Digital Media in Learning (Q2)

The use of digital media in learning contributes positively to the success of the teaching and learning process (Al-Rahmi et al., 2021). The use of digital media in learning has brought significant changes in the way technical education is delivered, particularly in how lecturers present material to students (Nicolaou et al., 2019). Lecturers often utilize various digital learning platforms such as Learning Management Systems (LMS) to organize instructional materials more systematically, use online presentation tools like PowerPoint (PPT) to present material in a more engaging way, and employ video-based media to provide explanations of content more effectively and efficiently (Mei et al., 2019). Technologies like these are used to simplify the visualization of more complex technical concepts, such as simulations and analysis of mechanical movements and CAD/CAM-based designs, which are often difficult to understand when using conventional methods (Cossich et al., 2023). With the use of digital media, students can observe engineering processes directly through simulations, making concepts that were previously abstract more tangible. From a safety perspective, this approach is also more secure, as it eliminates the risks associated with using physical equipment that could cause injuries (Makransky et al., 2019). The use of digital media in learning also makes it easier for lecturers to provide information and learning materials anytime and anywhere (Aduba & Mayowa-Adebara, 2022), and supports learning activities outside the classroom for students (H. Wang et al., 2022). In the context of mechanical engineering education, the use of digital media in learning is crucial to help students develop technical and analytical skills through independent exploration using digital tools that are relevant to the needs of the modern industrial world (Biletska et al., 2021).

Several forms of digital technology, such as Virtual Reality (VR) and engineering simulation tools, have been widely used in practical learning activities (P. Wang et al., 2018). By using digital media models like this, students are immersed in a learning environment that closely resembles real-world situations, and they can engage in learning anytime and anywhere (Kamińska et al., 2019). Virtual Reality (VR) is an example of how digital media can significantly aid both lecturers and students in achieving more effective and safer learning. For instance, students can participate in simulations of operating heavy machinery, such as lathe machines, milling machines, and welding machines, anywhere and far from the actual machines, ensuring safety from work-related accidents (Mystakidis et al., 2021). This digital technology and media not only provide students with the opportunity to master technical

skills in depth, but also allow them to repeatedly practice the skills they are learning without the risk of danger or equipment damage (Omolara et al., 2022). In addition, digital media such as engineering simulation tools can be used to develop and refine students' problem-solving skills in realistic situations, thereby enhancing the quality of learning as students gain practical experience, even when limited to the physical space of laboratories and workshops (Papanastasiou et al., 2019). The application of digital technology can also optimize learning time, provide more diverse and engaging simulations, and offer a more immersive experience for students in mastering their technical skills (Vecchiarini & Somià, 2023).

Digital media is used in the learning evaluation process, specifically in assessing students' work outcomes (Rodrigues et al., 2018). Task submission, assessment, and analysis of students' progress in learning can be conducted online (Elia et al., 2019). Assessment using digital media makes it easier for lecturers to provide feedback to students more quickly (Papademetriou et al., 2022). Lecturers can assign grades, and students can view their grades anywhere and anytime without having to wait for the next class meeting (Karay et al., 2020). Digital media is also commonly used by lecturers in discussion forums to facilitate communication, allowing both lecturers and students to meet anytime and anywhere (Mishra et al., 2020). This provides time efficiency for both lecturers and students, allowing them to interact and discuss outside of classroom learning activities (Coman et al., 2020).

The Impact of Digital Literacy in the Learning Process (Q3)

Digital literacy has a very positive impact on the continuity of mechanical engineering education, especially in utilizing digital technology to support the learning process (Fomunyam, 2019). The mastery of digital skills by mechanical engineering education lecturers plays a crucial role in enhancing the effectiveness of teaching and the learning experience of students (Hernandez-de-Menendez & Morales-Menendez, 2019). Lecturers with high digital skills can more easily use digital media to design and deliver interactive and engaging materials throughout the teaching process, from preparation to evaluation (Amhag et al., 2019). The digital literacy possessed by mechanical engineering education lecturers is not only used as a tool in teaching but also as a crucial factor in creating an interactive and dynamic learning environment that meets the needs of modern engineering education (Dai, 2024).

One of the main impacts observed in relation to digital literacy in learning is the ability of lecturers to use various digital media in the teaching process (Morgan et al., 2022). The use of digital media in online learning makes it easier for lecturers to deliver material in a more flexible and interactive way, ensuring that students do not become bored (Egielewa et al., 2022). By using digital media based on online learning, lecturers are not only assisted in presenting material in an engaging way but also help students access and study the material outside of class hours (Muthuprasad et al., 2021). Students can access the materials provided by lecturers anywhere and anytime to support self-directed learning

according to their individual capabilities (Ferri et al., 2020). With the presence of digital media, communication between lecturers and students becomes more open, allowing for discussions at any time without being limited by space and time (Zarzycka et al., 2021). This creates a learning environment that is more responsive and dynamic, tailored to students' needs, while also providing space for students to develop their digital skills (Parvin, 2020).

Digital literacy can help lecturers deliver lessons using various available digital media to make learning more diverse, such as utilizing animations, 3D models, and digital simulations, in order to enrich students' learning experiences when studying complex concepts in the field of mechanical engineering education (Basilotta-Gómez-Pablos et al., 2022). Some concepts in mechanical engineering, such as material mechanics, fluid mechanics, and machine dynamics, can be more easily learned by using animation or simulation media to provide a more realistic and interactive visualization (Qi et al., 2021). The learning model using digital media can help students apply the theories and knowledge they acquire into more real-world conditions (Al-Mamary, 2022). Digital literacy, both directly and indirectly, also supports project-based learning (PjBL) models, creating a learning environment where students collaborate in groups to solve problems and tasks that are relevant to the real-world industry (Al-Abdullatif & Gameil, 2021). By using digital media such as CAD/CAM or similar simulation applications, students can be supported in working on projects related to design and manufacturing digitally, where these competencies are highly relevant to the workforce (Spasova & Ivanova, 2020). This digital media can also assist students in practical and efficient laboratory-based learning, where they can experiment without being limited by the physical space of the laboratory (Kolil et al., 2020).

The lecturers' proficiency in digital literacy also impacts the process of assessment and evaluation of students' learning progress in real-time (Blau et al., 2020). By using analytical-based digital media and Learning Management Systems (LMS), lecturers can continuously monitor students' learning progress and provide fast and accurate feedback (Cotton et al., 2024), and can make adjustments to teaching methods that align with students' needs and industry demands (Alenezi, 2023). Thus, the learning process can proceed smoothly and in line with the academic objectives that have been established.

However, behind the digital literacy that offers many positive benefits, this research also found several challenges and difficulties faced by mechanical engineering education lecturers in applying technology and digital media in the teaching process. One of the most evident challenges is the unequal mastery of digital technology among mechanical engineering education lecturers (Ahmed & Opoku, 2022). Some lecturers are unable to fully utilize technology in teaching due to a lack of adequate digital skills (Gudmundsdottir & Hatlevik, 2018). Additionally, limited access to infrastructure, technology, and required software remains a challenge for some mechanical engineering education lecturers and students, particularly in areas where technology has not been fully optimized (Barakabitze et al., 2019).

The lack of training programs and institutional support also serves as a barrier to the broader implementation of technology in teaching activities (Al-Ghurbani et al., 2022).

CONCLUSION

Digital literacy skills for mechanical engineering education lecturers are crucial in addressing the advancements of the Industrial Revolution 4.0 era, as they enhance the quality of learning and improve students' competencies in preparing for the workforce. The conducted research shows that most mechanical engineering education lecturers have mastered basic digital applications and tools supporting technical learning, such as CAD/CAM and online learning technologies, although there is a significant gap in technology proficiency between junior and senior lecturers. Lecturers can utilize technology more effectively in mechanical engineering education through intensive and continuous training programs, enabling the creation of interactive and innovative learning environments. In the future, similar research can focus more on aspects of cybersecurity and digital ethics in relation to mechanical engineering education, as well as develop more structured training models. The findings of this research can help accelerate the adoption of new technologies and improve the overall quality of engineering education, thereby shaping student competencies to meet the demands of an increasingly digital and technology-driven workforce.

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