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COMPARATIVE ANALYSIS OF ONLINE INTERDISCIPLINARY TEACHING TOOLS FOR INDUSTRIAL DESIGN EDUCATION

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ABSTRACT

The COVID-19 pandemic prompted a shift to online learning in industrial design education. This study analyzes the adaptation of two separate online platforms to interdisciplinary education during the first two years of the lockdown period: Facebook Classrooms in the first year and Microsoft Teams in the second. Surveys conducted with students after each term assessed the platforms' impact on technical instruction, peer interaction, and engagement. The results, derived through Factor Analysis and validated with a reliability score exceeding 0.85, highlight the strengths and limitations of both platforms in general and multidisciplinary industrial design education. Facebook Classrooms enabled flexible, informal collaboration and resource sharing but lacked essential design tools and task management features, limiting its suitability for comprehensive industrial design education. In contrast, Microsoft Teams provided a structured and professional environment with tools for live lectures and real-time feedback, ideal for managing complex projects. However, it also has its disadvantages, primarily due to its complexity and cost. The findings and conclusions presented at the end of the study offer insights into enhancing online teaching methods in hybrid education in various fields.

Keywords: Online education, Design education, Dedicated web learning tools, Social media for online learning, Technical instruction.

1 INTRODUCTION

Over the past few decades, there have been various efforts and investments in advancing educational technology and developing digital skills [1]. While some of these have been notable examples of innovation and success, many were short-lived, limited in scope, or had minimal impact at a systemic level [2], [3]. This is partly because the full potential of digitalizing education was not widely recognized or understood, or even felt necessary [4]. The COVID-19 crisis marked a turning point, forcing educational institutions worldwide to quickly shift to digital platforms, as there was no alternative for continuing education. While this shift proved the value of online education to educators, students, and parents [5] it also revealed the challenges that must be addressed to effectively integrate digital technologies into education systems [6].

Amid the COVID-19 pandemic and the efforts to adopt new teaching methods, both governments and businesses have made significant additional investments in the research and development of digital education platforms [7]. Software and hardware for numerous digital education platforms have been developed, new teaching and learning modes integrated into existing platforms, diverse digital teaching materials have been created, and schools have actively implemented these digital platforms into their curriculum, aiming to enhance student learning outcomes [6].

Various software packages, which are called learning management systems (LMS), such as Moodle, Blackboard, Microsoft (MS) Teams, Adobe Connect, Canvas, Google Classroom, Zoom, and Team-Link, have played crucial roles in facilitating online education at both institutional and individual levels [8]. Simultaneously, social media platforms like Facebook, Instagram, Twitter, LinkedIn, WhatsApp, and YouTube have introduced new forms of interaction to be used for education purposes, transforming simple social media messaging between teachers and students to a higher level of controllable information exchange [9], [10]. This showed that the social media platforms can be adapted as non-cost tools in the teaching and learning process [11]. When used appropriately, they can enhance communication and collaboration, improving the overall teaching-learning experience [12]. At the beginning of the pandemic, when the abrupt and unexpected lockdown started, as our university also switched to online education, we needed to quickly review the existing research about online education to establish an effective teaching environment as soon as possible. As we researched, we became more adept at using online systems, leveraging their capabilities. We tested several separate systems and settled on Facebook Classrooms for use throughout the crisis period. But in the next year, as our university bought the Microsoft Teams learning management system, we had to switch from Facebook to Microsoft. That allowed us to comparatively and methodically assess two systems. This study presents an assessment of the two online education platforms in terms of their capabilities in interdisciplinary teaching in the industrial design field.

2 LITERATURE REVIEW

Following the lockdown period, we analyzed post-pandemic studies to compare their findings with ours, ensuring a concise yet insightful perspective on our research. The literature reviewed primarily explored the application of online tools in education and their pedagogical effects. Additionally, we examined studies across various disciplines that utilized Factor Analysis for data processing. A curated summary of this literature is presented below.

2.1 Studies on Digital Education

These studies started as early as 2001 with Chang [13]. He investigated an online teaching system based on continuously updated student portfolios. He used a questionnaire to gather data from the participants about the use of the system, and after processing the data, he listed the positive benefits of using the web in education.

Chumley et al. [14] studied web-based medical education and investigated older studies, 206 in total from the 1990s, classified and compared them to more recent studies in terms of pros and cons, and proposed new subjects and ideas to further investigate and apply in future research.

Kay [15] investigated the use of Web-Based Learning Tools (WBLT) in science classrooms between grades 7 to 10, analyzing feedback from 11 teachers and 371 students. Teachers viewed the tools positively, praising their design, engagement, and learning benefits, while students, though more critical, still valued their visual scaffolding, usability, and engagement features. His study showed that the student performance improved significantly across cognitive domains like remembering and analyzing, with older students showing greater gains. His conclusions stated that WBLTs enhanced science education and were effective across both middle and secondary school levels.

Wasim et al. [16] examined how educators utilized web-based learning (WBL) in higher education to support both their own and students' learning. They highlighted the advantages of WBL, including overcoming barriers of distance and time, achieving cost efficiency, and introducing innovative teaching methods. They stated that the web was increasingly employed as a tool for formal education and as a platform for delivering online learning programs, and pointed out challenges that might arise from this situation, such as social isolation, high initial expenses, and technical difficulties.

Fleischmann [17] examined how the COVID-19 pandemic forced design educators to transition from face-to-face studio teaching to online platforms using web-based tools and their optimism about online learning's potential. However, he raised some questions about online design education's persistence as a core element of post-pandemic curricula and the balance between online and physical classroom education.

Milovanovic et al. [18] analyzed the shift in architectural education during the COVID-19 pandemic, focusing on new teaching methods, digital environments, and curriculum improvements. They explored the potential of online workshops to enhance learning in emergency design contexts in a workshop titled "COVID-19 Challenges: Architecture of Pandemic,". Their findings highlighted the opportunities and limitations of using online architectural education in the case of global crises, emphasizing the need for innovative approaches to current challenges.

Toprak et al. [8] examined the transition of Turkish universities to online education during the COVID-19 pandemic, following a decision by the Council of Higher Education in the 2019–2020 spring semester. By the 2020–2021 fall term, many universities continued online learning, aligning with practices in some developed countries. The study evaluated the digital readiness of Turkish universities, assigning an average score of 4.1 out of 10 based on their web presence, and proposed a digitalization index and a roadmap for transitioning to new-generation digital universities.

Desai et al. [19] discussed the shift from traditional design studios to remote teaching during the COVID-19 pandemic, focusing on the Global Design Studio, a collaboration between Industrial Design in Australia, Interaction Design in Canada, and User Experience Design in Germany. GDS aimed to provide cross-disciplinary experiential education by sharing resources and working on projects like creating an interactive mannequin for teaching. The study identified challenges in remote collaboration, cultural differences, and group work, while proposing a GDS model to support cross-disciplinary experiential education in online settings.

Kyuchukov [20] explored the impact of the COVID-19 pandemic on higher education in Bulgaria, focusing on the shift to online learning in Industrial Design education. It assessed how the transition affected education quality, students' reactions, and lecturers' perceptions. The study discussed the benefits and challenges of online learning, addressing whether it was seen as an opportunity or a threat in this period of transformation.

Ong et al. [21] explored industrial engineering students' preferences for online learning during the COVID-19 pandemic. Using conjoint analysis, data were gathered from 126 students across three educational levels: undergraduate, fully online master's, and master's/doctorate. The results showed varying preferences based on educational level. Undergraduate students preferred multiple-choice final requirements, non-modular term style, and no seatwork. Fully online master's students preferred a mixed delivery type, layout, and no seatwork. Master's and doctoral students favored publication-based final requirements, no seatwork, and a mix of delivery types. The study highlighted that students were technologically inclined, preferred self-paced learning, and still valued teacher guidance.

Bernardo and Duarte [22] discussed a future forecast study where higher education educators in industrial design imagined teaching and learning with Virtual Reality (VR) integrated into design studios twenty years from now. Participants speculated on how VR technology would transform design activities, student behaviors, and studio dynamics. The majority expected more engaged, collaborative students with deeper knowledge of their projects, though some were concerned that increased digital interaction might weaken material connection and sensibility. The study highlighted potential impacts on the design process, curriculum, teaching methods, and student development, suggesting that the adoption of VR could bring far-reaching changes beyond just the design studio environment.

Yavuz [23] explored the advantages and limitations of online juries in industrial design education, especially considering digitalization during the COVID-19 pandemic. The study involved observing online juries and conducting semi-structured interviews with students and jury members at the Department of Industrial Design at Middle East Technical University. Findings revealed both conveniences and difficulties faced by participants. Based on these insights and consideration of traditional jury dynamics, the study proposed potential design improvements for online platforms to better support jury experiences.

Izadpanah [24] investigated the experiences of second-year students and instructors in the Interior Architecture and Environmental Design department at Akdeniz University, which also shifted to an online design studio due to the COVID-19 pandemic. Data from a questionnaire survey is analyzed, revealing that students made significant progress in their design work and expressed satisfaction with the online studio environment.

Martins [25] discussed an alternative approach to design education during the development of a digital interface for the COVID-19 Case Record Form, created by the World

Health Organization. The project, carried out by students from the Superior School of Industrial Design at the State University of Rio de Janeiro, took place in April 2020. It highlighted pedagogical and methodological challenges faced in this emergency context, focusing on interactive design and collaboration between students and educators.

Sobaih et al. [26] investigated students' learning experience with Microsoft (MS) Teams compared to other social media systems such as WhatsApp and Facebook during and post the COVID-19 pandemic for teaching and learning purposes in public universities in Egypt. They used descriptive statistics on IBM SPSS software to process data they collected from the students through surveys. They listed the pros and cons of using MS Teams versus social media systems comparatively according to criteria like access to learning resources, support, motivation, participation in course activities, assessments, and feedback.

2.2 Studies that Use Factor Analysis Methodology

This part of the literature review summarizes selected articles utilizing factor analysis as a method.

Rodrigues-Moreno et al. [27] analyzed students' use of digital tools and social networks during the COVID-19 pandemic. Data was collected from 581 students by using a validated Likert questionnaire. The research employed exploratory factor analysis and structural equation modeling to examine digital competence. Results highlighted that the use of virtual tools for teamwork and YouTube for communication were key factors in improving students' skills during the pandemic.

Choe and Borrego [28] used factor analysis to identify the attributes of engineering design students. They collected data by interviewing engineering faculty members, engineers from industry, and processed the gathered data by using exploratory factor analysis. They used detailed definitive tables to present their analysis results, which point out that engineering students considered to have multiple career options for their future, and advisors and education researchers should be able to support them with multiple education options, methods, or paths tuned according to student needs.

Azmi et al. [29] analyzed employers' needs and expectations from qualified employees. They conducted surveys with employers and used Factor Analysis to process data. They stated that to supply the employees needed by the industry in time, the education system should be quick to adapt to all kinds of changes in the industry that a crisis may cause.

Fahrner and Schüttoff [30] researched the sport and recreation environment for employers' skill expectations. They applied factor analysis on data gathered from employers and produced a list of required skills with their interpretations and concluding remarks.

Adiguzel and Cakir [31] investigated the factors affecting the motivational drives of industrial engineers employed in Turkish firms. They determined the sources of motivation for industrial engineers and interpreted them in detail, and pointed out that professional satisfaction comes as the greatest drive for the participants.

Zhu et al. [32] investigated aesthetic expressions in environmental design schemes by using creativity assessment indicators. They performed exploratory factor analysis to determine the main factors affecting design creativity.

Sobaih et al. [33] investigated the university education in Egypt during the pandemic and noted that several universities have urged their faculty members to utilize free communication platforms like Facebook, WhatsApp, YouTube, Google Classroom, and Zoom. They employed factor analysis to examine the outcomes of the mandatory adoption of online tools in education, identifying key factors influencing their effectiveness in engaging students.

Özsoy [34] studied interdisciplinary educational activities based on electromechanical product applications in industrial design programs, using factor analysis to identify the key factors influencing students' interests and expectations toward such activities, which combine design, electronics, prototyping, and system integration.

3 THEORY-BASED DISCUSSIONS ON THE PEDAGOGICAL EFFECTS OF LEARNING MANAGEMENT SYSTEMS AND SOCIAL-MEDIA-BASED EDUCATIONAL TOOLS.

The COVID-19 pandemic brought an unprecedented shift in education, forcing institutions worldwide to transition to online learning. For disciplines like industrial design, which depend on collaboration, visual communication, and hands-on activities, this shift posed unique challenges. Literature so far has reviewed the use of numerous online tools for general education; some are dedicated education tools, and others are social media or broadcasting tools. Among those tools investigated, the literature lacked a comparative analysis of using Microsoft Teams (an established LMS tool) and Facebook Classrooms (A social media platform). So, we aimed to perform this assessment, explore their applications, benefits, pedagogical impact, and limitations in the context of industrial design education by using data obtained from our Machines and Mechanisms (MAKEL) lectures.

Industrial design university curricula are deeply rooted in studio-based learning. Students engage in hands-on creation, collaborate on projects, and receive immediate feedback from peers and instructors [35]. With the pandemic, the absence of physical spaces necessitated tools for virtual collaboration, platforms for real-time communication, reliable methods for sharing visual and technical design files, and solutions for fostering creativity and engagement [36]. Microsoft Teams and Facebook Classrooms offered unique tools to address these needs. Before delving into their details, it might be useful to investigate their use from a pedagogical point of view. The pedagogical effects of Learning Management Systems (LMS) and social media-based educational tools have been widely discussed in educational theory, particularly through the lenses of constructivism, connectivism, and collaborative learning theories [37]. These discussions highlight the impact of technology on knowledge acquisition, student engagement, and learning outcomes.

3.1 Constructivism and LMS in Education

Constructivist learning theory, largely influenced by Piaget and Vygotsky, suggests that students construct knowledge through active engagement rather than passively receiving information [38]. LMS platforms like Microsoft Teams, Moodle, and Blackboard align with this theory by providing structured learning environments where students can access materials, complete assignments, and receive feedback [39]. These systems promote scaffolded learning, where students progress through complex topics in a guided manner, reinforcing deep understanding [40]. Additionally, LMS features such as discussion forums, quizzes, and interactive modules support self-regulated learning, allowing students to engage with content at their own pace [41].

3.2 Connectivism and Social Media-Based Learning

Connectivist learning theory, introduced by Siemens and Downes, emphasizes the role of digital networks in modern education [42]. Social media platforms like Facebook Groups, LinkedIn, and Twitter create decentralized learning environments, where knowledge is co-constructed through discussions, shared resources, and real-world interactions [43]. Unlike LMS, which often follows a hierarchical structure, social media fosters informal, dynamic, and interactive learning through peer-to-peer exchanges. This aligns with the idea that learning occurs through continuous interaction within digital networks, preparing students for real-world professional collaborations [44].

3.3 Collaborative Learning and Technology-Enhanced Education

Theories of collaborative learning, such as those proposed by Dillenbourg and Roschelle, highlight the importance of knowledge co-construction and group-based problem-solving [45]. Both LMS and social media tools contribute to collaborative learning, but in different ways. LMS platforms enable structured collaboration through group projects, shared documents, and discussion boards, maintaining a formal learning structure [46]. In contrast, social media tools encourage spontaneous and informal collaboration, where students can engage in discussions, share insights, and receive feedback from a broader network of peers and professionals [47].

3.4 Comparing LMS and Social Media for Pedagogical Impact in Literature

From a pedagogical standpoint, LMS platforms support instructor-led learning, assessment-driven progress, and structured content delivery, making them ideal for formal education settings [48]. Social media-based tools, on the other hand, emphasize learner autonomy, engagement, and real-world networking, which can enhance informal learning and industry connections [49]. However, one challenge of social media-based learning is the lack of content moderation and academic rigor, which LMS platforms address through controlled environments and structured assessments [50].

Both LMS and social media tools contribute to educational effectiveness by catering to different learning needs. While LMS provides a structured and assessment-driven framework, social media fosters interactive, networked, and experiential learning. A balanced integration of both can maximize pedagogical benefits, ensuring both academic depth and real-world applicability in modern education [51].

4 ABOUT SELECTED LEARNING MANAGEMENT AND SOCIAL MEDIA SYSTEMS

In this section, we'll investigate the features, applications, benefits, and limitations of the Facebook Classrooms Social Media environment and Microsoft Teams Learning Management System we used in this research.

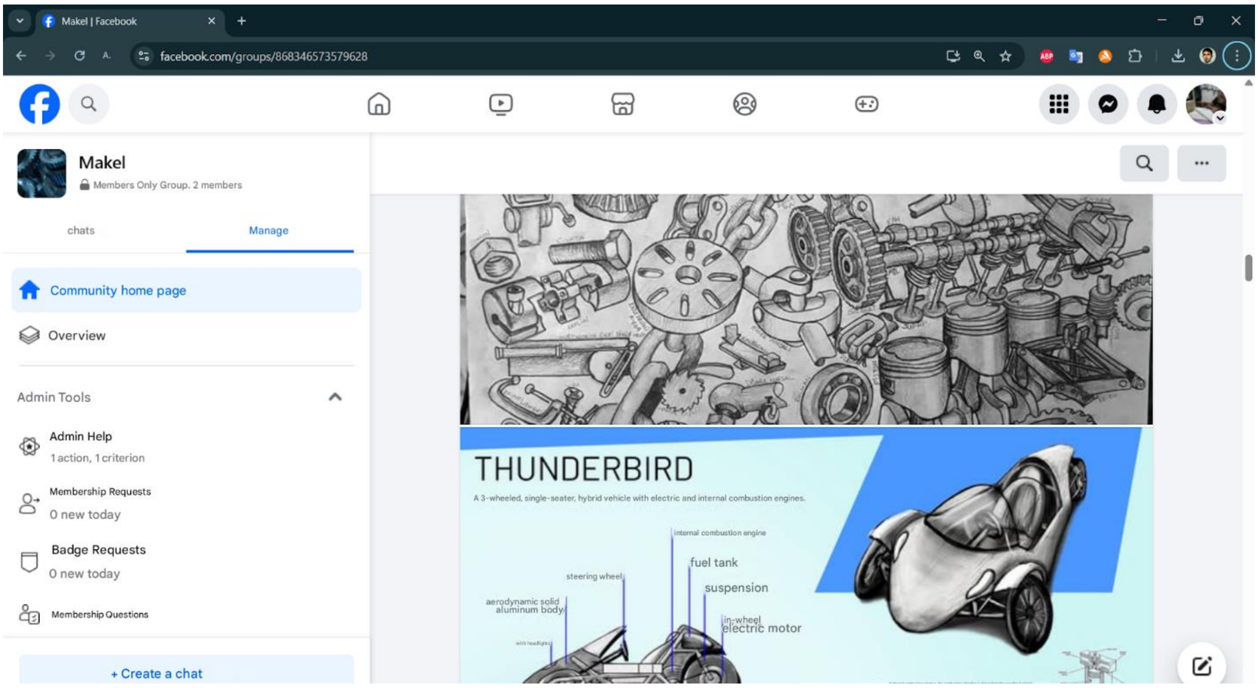

Figure 1. Facebook Makel Classroom Page.

4.1 Facebook Classrooms

Facebook, widely known for its social networking features, introduced Facebook Classrooms, seen in Figure 1, during the pandemic as an educational tool. Its informal, community-driven approach contrasts with the structure of Microsoft Teams, making it a good choice for fostering creativity[52].

4.1.1 Features:

- *Social Engagement:* Students and instructors could share ideas, photos, and videos in an intuitive format, mimicking real-world design studio dynamics.
- *Groups and Events:* Private groups allowed focused discussions, while event features enabled scheduling of critiques, workshops, and webinars.
- *Live Streaming:* Facebook Live supported real-time lectures and Q&A sessions.

- *Resource Sharing:* Posts in groups could include files, links, and media, allowing for quick and informal sharing of inspirations and references.

4.1.2 Benefits:

- *Ease of Access*: Most students were already familiar with Facebook, reducing the need for training.
- *Cost-Free:* Ideal for institutions or students with limited resources.
- *Engagement and Motivation:* The social nature of Facebook helped create a sense of community and collaboration.

4.1.3 Limitations:

- *Privacy Concerns:* Using a public platform raised issues about data security and professional boundaries.
- *Limited Design Tool Integration:* Unlike Teams, Facebook lacked features for advanced design file sharing or integrations with professional software. Images shared in messages and comments were difficult to find later.
- *Video Broadcasting Instead of Video Conferencing:* Facebook lectures can only be made as video broadcasts, and students cannot join the vocal conversation as they can do within other video conferencing systems. But they still can ask questions through writing comments under videos or by sending messages. Unfortunately, the time required for the instructors to see and respond to these text messages slows down the two-way communications during lectures and may even slow down the lecture itself.
- *Lack of Formality:* Its casual nature and social media distractions within itself sometimes hinder academic rigor and structured learning.

4.1.4 Industrial Design Specific Properties of Facebook Classrooms

According to our experience, we gained during our study, Facebook Classrooms serves as a more informal and community-driven learning environment, encouraging peer-to-peer discussions, resource sharing, and collaborative learning outside formal classroom settings. Students can share sketches, 3d models, renderings, and product concepts by using Facebook's file sharing system or attach images to their comments or messages. The platform's multimedia integration makes it easy to upload images, videos, and design tutorials, facilitating the visualization of product prototypes and simulations. The students can receive feedback both from their classmates and instructors on openly shared files. Facebook Classrooms also allows live discussions, polls, and surveys, which are useful for gauging student understanding and engagement. Furthermore, as the platform is open to anybody on the internet, Facebook gives students the ability to connect with people from the outside world, such as industrial designers, alumni, and other professionals who can offer real-world insights. Automatic notifications supplied by the system help students to stay informed about deadlines, events, and additional learning resources.

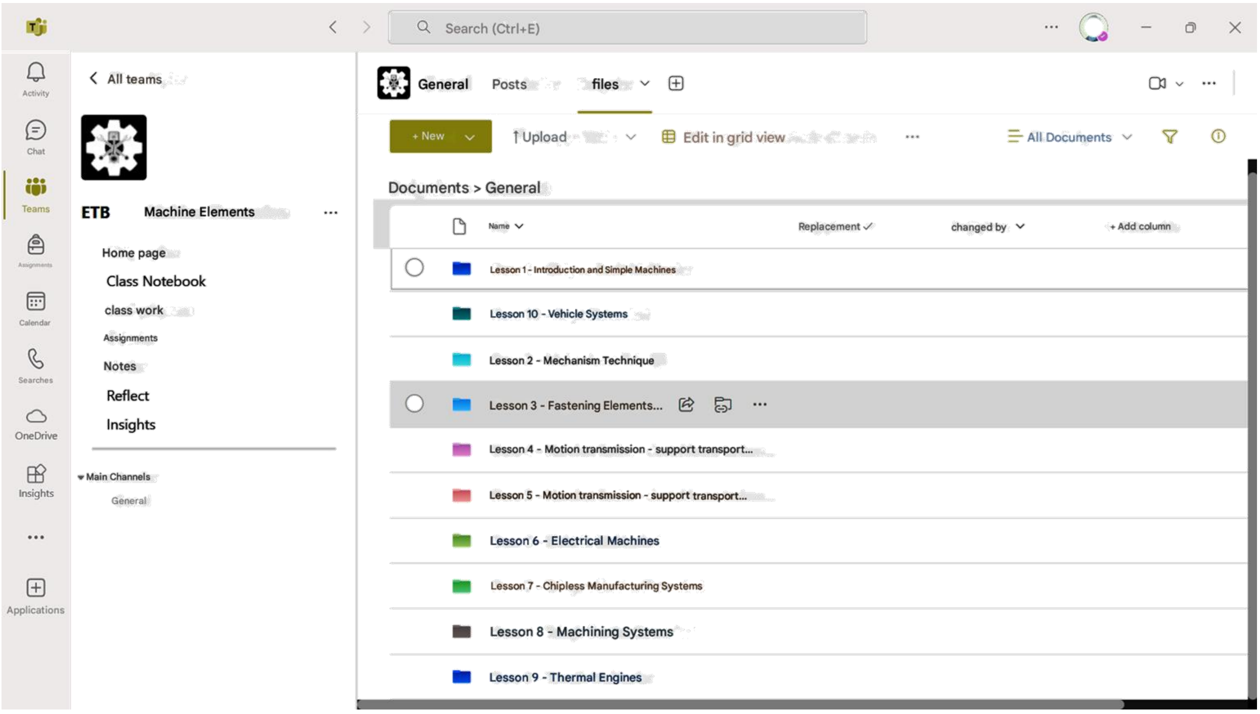

Figure 2. Microsoft Teams Makel Lecture Page.

4.2 Microsoft Teams Learning Management System

Although it was first announced in the late 1990s and developed in the early 2000s, MS Teams LMS gained prominence in recent years as a professional, feature-rich system ideal for structured and large-scale education. It provided robust tools that suited the technical and collaborative nature of industrial design courses[53]. The MS Teams Makel Lecture page is seen in Figure 2.

4.2.1 Features:

- *File Sharing and Integration:* MS Teams allowed seamless sharing of large 2D CAD files, 3D models, and Photoshop projects. Integration with MS Office, Adobe Creative Suite, and other industry-standard tools made it convenient for students and educators.

- *File security:* With the files directly saved on Microsoft OneDrive cloud servers, the users don't need to remember to save their work continuously, as the system automatically does it each time a file is altered. This prevents losses due to power or hardware failures. As earlier versions of the files are also kept, the user can revert to an older version of a design if needed. This is a very useful feature in situations in which multiple wrong design changes or mistakes are made, as the user can simply revert to a previous version of the file, instead of correcting the mistakes one by one.
- *Channels for Collaboration:* Dedicated channels for specific projects or courses encouraged focused discussions.
- *Video Conferencing and Recording:* High-quality video calls enabled critiques, live demos, and feedback sessions. Recordings allowed students to rewatch earlier lectures and critiques when they needed them.
- *Task Management:* Built-in features like assignments, calendars, polls, and project trackers support structured learning.

4.2.2 Benefits:

- *Centralized Communication:* Teams functioned as a one-stop hub for course materials, announcements, and discussions.
- *Scalability and Security:* Institutions could rely on its advanced infrastructure to handle large classes and protect sensitive data.
- *Customizable Features:* Integration with third-party apps tailors the platform to specific course needs.

4.2.3 Limitations:

- *Steep Learning Curve:* New users, particularly those less tech-savvy, often require more time to adapt.
- *Internet Dependence:* High bandwidth requirements occasionally create difficulties for students who live in remote areas and/or have slower connections.
- *Need for Better Computers:* As the students will need to run a large learning management system together with their usual CAD and other software, their PCs

will need to have a faster CPU, more RAM & disc storage, and preferably multiple screens.

- *Reduced Spontaneity:* Conversations in Teams tend to be more controlled and formal, limiting organic interactions.

4.2.4 Industrial Design Specific Properties of Microsoft Teams LMS

According to the experience we gained during our study, Microsoft Teams provides a structured course management system where instructors can organize materials in their preferred directory structure. The shared files can be viewed by a selected group of students in the Microsoft Teams environment and, if permitted by the instructor, downloaded onto the students' computers. The files can also be simultaneously shared through Microsoft OneDrive, enabling a student who has installed OneDrive software on his/her computer to have the latest files automatically as changed by the instructor. Assignments can also be given to and collected from the students, with deadlines being efficiently controlled by the system, with necessary announcements made to both the students and the instructors. Additionally, MS Teams also offers built-in assignment grading and feedback options. The live lecture and recording capabilities allow students to rewatch saved videos later at their convenience. The platform also integrates with design tools such as SolidWorks and AutoCAD over MS OneDrive, enabling collaborative editing and cloud-based storage of CAD models. Its collaborative workspace supports team projects, allowing students to co-develop design files and do presentations to each other by using the integrated PowerPoint program. The whiteboard and group annotation features assist in doing collaborative design sketches, mechanism studies, and virtual assemblies.

4.3 Comparative Analysis of Facebook Classrooms and Microsoft Teams for Industrial Design Education.

Microsoft Teams and Facebook Classrooms each offer distinct advantages and limitations for general education as summarized in Table 1.

Table 1. Summary of the specifications of both platforms.

Feature	Facebook Classrooms	Microsoft Teams
File Sharing	Basic, limited to simple files	Highly secure, supports large design files
Collaboration	Informal, open discussions	Structured channels for teamwork
Video Features	Basic live streaming	High-quality meetings, recordings
Accessibility	Easy-to-use, lightweight	Requires training, heavier on hardware
Engagement	Creative, community-driven	Formal, task-focused
Tool Integration	Minimal	Extensive
Cost	Free	Requires institutional licensing

The two systems offer distinct functionalities that cater to both general education and industrial design-specific tasks. While Microsoft Teams may initially appear superior, Facebook Classrooms' zero-cost advantage levels the playing field. Therefore, to make a well-informed comparison, we employed a more advanced methodology, analyzing key factors influencing students' platform preferences, as detailed in the following section.

5 METHODOLOGY

In this phase, data obtained from surveys done during the initial two years of online education in the COVID-19 lockdown were used. In the first year, Facebook Classrooms was used as the online teaching platform. A classroom group has been opened on Facebook for the Machines and Mechanisms (MAKEL) lecture. In this group, live lecture videos were aired, questions answered, and assignments were given to students. Photo albums carrying students' names are used to gather assignments. At the end of the semester the questionnaire shown in Table 2 was prepared, and it was sent to the students using the Google Forms system. Their thoughts about various aspects of the online MAKEL course were recorded, easily accessible by the instructor through the Google platform. 45 students (38 female and 7 male) participated in this first semester survey and supplied data about the Facebook Classrooms platform.

In the following year, Microsoft Teams was used as the education platform. Separate class Teams were created by the faculty for each lecture, and students are added to these teams. Then the Teams are handed over to the instructors. At the lecture's end, the same online Google Forms questionnaire shown in Table 2 was again sent to the students. Their thoughts about various aspects of the online MAKEL course were gathered. A total of 44 students (35 female and 9 male) participated in the second survey conducted on the Microsoft Teams platform, an amount which is very close to the first year's count of 45. After the second year is completed, the evaluation phase started. The data collected from the students in two consecutive semesters was processed by the factor analysis method to obtain numerical findings in easy-to-interpret tables.

Table 2. Course survey conducted on the Facebook platform.

QUESTIONS	1	2	3	4	5
A.1. I'm good at working with a computer.					
A.2. I like to work with computers					
A.3. I'm comfortable working with the computer					
B.1. The social media account opened on Facebook for the teaching of the lesson was well organized.					
B.2. It was easy to use the social media account opened for the teaching of the lesson.					
B.3. It was easy to follow the instructions on the social media account opened for the course					
B.4. I was able to follow both the course content and the announcements through the social media group of the course.					
C.1. Working through a social media group has helped me learn.					
C.2. The feedback made through the social media group helped me learn.					
C.3. The graphics and animations used in the lecture helped me learn.					
C.4. I related what I learned in the units to the concepts I had learned in previous units.					
C.5. The newly acquired knowledge on the course confirmed and improved my pre-class knowledge.					
C.6. The assignments were instrumental in my learning the lesson better.					
C.7. Additional documents related to the course shared in the social media group enabled me to learn the course better.					
C.8. The fact that the course was held on social media allowed me to share information with my friends.					
D.1. I liked the overall structure of the social media group in which the course was taught.					
D.2. I found the social media group in which the course was taught interesting.					
D.3. The fact that the lesson was taught through the social media group made learning fun.					
D.4. The mechanisms section of the course, which was taught through the social media group, was useful.					
D.5. I used the social media group whenever I wanted, at random intervals.					
D.6. If I were to take the course again, I would like it to be taught again on the social media group.					
D.7. I found the web-based training system useful					
D.8. I prefer to take this course with the traditional methods that the teacher teaches in the classroom.					

5.1 Demographics of the Participants

The participants were 89 industrial design students, volunteered among 160 students who attended the course as two separate classes in two consecutive semesters (approximately 80 students for each semester). All participants gave their consent for the data collected during the classes to be used in this research. Their demographics are as follows:

Gender composition:

- 73 females (82%).
- 16 males (18%).

Academic Year:

- 2nd year: 45 students (37 females, 8 males).
- 3rd year: 44 students (36 females, 8 males).

Age Range:

- Majority aged 20–22 years.

Fields of Interest within Industrial Design:

- Product Design: 28 students (22 females, 6 males).
- Furniture Design: 20 students (16 females, 4 males).
- UX/UI Design: 23 students (19 females, 4 males).
- Sustainable Design: 18 students (all females).

Technological Proficiency:

- All students have CAD-capable laptops.
- Familiarity with emerging technologies such as AR/VR: 25 students (including 6 males).

Hometowns and Residence:

- Large Cities: 60 students (e.g., Istanbul, Ankara, Izmir).
- Smaller cities or towns: 29 students (e.g., Trabzon, Eskişehir).
- Living arrangements:
  - Campus or nearby housing: 65 students.
  - Commuting or living with family: 24 students.

Socio-economic Background:

- Low-income families: 20 students (receiving financial aid).
- Middle-income families: 60 students.
- High-income families: 9 students.

Extracurricular Activities:

- Members of design-focused clubs: 40 students.
- Internships in industrial design firms: 22 students.
- Participation in design competitions: 35 students.

Language Skills:

- Fluent in Turkish and English: 32 students.
- Additional languages (e.g., German, Italian, French): 7 students.
- Single language only (Turkish): 57

Learning Preferences and Tools:

- All students actively use digital tools like Facebook and Microsoft Teams for collaboration.
- 50 students prefer hands-on prototyping and workshops in addition to theoretical learning.
- 30 students express strong interest in sustainability-focused design.

5.2 What is Factor Analysis?

Factor analysis is a statistical technique used to uncover underlying relationships between observed variables by grouping them into unobserved factors. It helps researchers reduce data complexity and identify patterns that may not be immediately apparent. This method is widely applied in fields such as psychology, social sciences, and finance [54]. In factor analysis, the observed variables are correlated with one another because they share common influences, known as factors. These factors are not directly measured but are inferred from the data. The strength of the relationship between a variable and a factor is expressed through factor loadings, which indicate how much each variable contributes to a given factor. Eigenvalues represent the amount of variance explained by each factor, helping researchers to determine the number of factors to retain in their analysis. Additionally, factor rotation techniques, such as Varimax or Promax, are often applied to simplify the factor structure and make the results more interpretable [55].

There are two main types of factor analysis: Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA is used when researchers do not have a predefined expectation of how variables should group and aim to identify potential factor structures. CFA, on the other hand, is used to test whether a hypothesized factor structure fits the data, making it a more rigid and theory-driven approach[56]. In industrial design, factor analysis can be particularly useful for identifying users' product preferences, analyzing usability factors that influence product adoption, and understanding how users perceive various aesthetic and functional aspects of a product[57]. By reducing a large set of variables into a smaller number of meaningful factors, designers and researchers can make more informed decisions in product development, improving both user satisfaction and market success[58].

5.3 Performing the Factor Analysis and Ensuring the Reliability of the Results.

In factor analysis, the general rule suggests a minimum of 5 to 10 participants per variable, with an overall sample size of at least 100 to 300 respondents for stable and reliable results[59]. Given that our sample size of 89 met or exceeded these benchmarks, it was considered statistically sufficient. Moreover, communalities above 0.50 and factor loadings greater than 0.40 further validated the adequacy of our sample.

The factor analysis in this research was applied in a structured process to identify underlying dimensions in the collected data. First, we conducted data screening to check for missing values, outliers, and the suitability of the dataset[60]. The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy [61] and Bartlett's Test of Sphericity [62] were used to confirm that the data met the necessary conditions for factor analysis. A KMO value above 0.60 and a significant Bartlett's Test ($p < 0.05$) indicated that factor analysis was appropriate.

Then we performed Exploratory Factor Analysis (EFA) using Principal Component Analysis (PCA) [63]as the extraction method. Factors were retained based on eigenvalues greater than 1, and a varimax rotation [64]was applied to enhance factor interpretability. Items with factor loadings below 0.40 or significant cross-loadings were removed to ensure a clear factor structure.

After determining the factor structure, the robustness of the factor structure was confirmed through Confirmatory Factor Analysis (CFA), where model fit indices (CFI $\geq$0.90, RMSEA $\leq$0.08) indicated a well-fitting model, also reinforcing that the sample size was adequate for producing valid and reliable findings. Goodness-of-fit indices such as Chi-square/df ratio ($\leq$3), Comparative Fit Index (CFI $\geq$0.90), and Root Mean Square Error of Approximation (RMSEA $\leq$0.08) [65]were used to further check the model's fit.

The final factor structure was then interpreted based on theoretical alignment and practical relevance. This systematic approach ensured that the extracted factors were reliable, valid, and meaningful for understanding the relationships within the dataset.

6 FINDINGS AND THEIR INTERPRETATION

Factor loadings represent the correlation between the observed variables and the latent factors. A higher loading (typically above 0.5) indicates a stronger relationship between a variable and the factor. Variables that load highly on the same factor are considered to share a common underlying dimension. Based on the variables that load heavily on factors, as seen in Tables 3 and 4, we assigned a name to each factor that reflects the common theme they represent.

Table 3. Factor analysis results for the course on Facebook Classrooms.

Items included in factor 1	***Factor loads***	***Factor 1- Reliability Analysis***
The mechanisms section of the course, which was taught through the social media group, was useful.	0.798	0.894
The newly acquired knowledge on the course confirmed and improved my pre-class knowledge.	0.773	
I related what I learned in the units to the concepts I had learned in previous units.	0.728	
The graphics and animations used in the lecture helped me learn.	0.666	
Working through the social media group helped me learn.	0.523	
The feedback made through the social media group helped me learn.	0.501	
Items included in factor 2	***Factor loads***	***Factor 2- Reliability Analysis***
The fact that the course was held on social media allowed me to share information with my friends.	0.797	0.896
I liked the overall structure of the social media group in which the course was taught.	0.763	
I found the social media group in which the course was taught interesting.	0.714	
Additional documents related to the course shared in the social media group helped me learn the lesson better.	0.666	
The assignments were instrumental in my learning the lesson better.	0.61	
The fact that the lesson was taught through the social media group made learning fun.	0.589	
Items included in factor 3	***Factor loads***	***Factor 3- Reliability Analysis***
I like to work with computers	0.898	0.885
I'm comfortable working with the computer	0.884	
I'm good at working with a computer	0.855	
I found the web-based training system useful	0.579	
Items included in factor 4	***Factor loads***	***Factor 4- Reliability Analysis***
It was easy to follow the instructions on the social media account opened for the course	0.792	0.827
I was able to follow both the course content and the announcements through the social media group of the course.	0.781	
It was easy to use the social media account opened for the teaching of the lesson.	0.747	
The social media account opened on Facebook for the teaching of the lesson was well-organized.	0.731	

Based on the items included in Factor 1, the common theme seems to revolve around **learning enhancement and support through social media**. A suitable name for this factor could be: "**Social Media-Driven Learning Support**"

The items in Factor 2 suggest a focus on engagement, collaboration, and enjoyment facilitated by the social media-based course structure. A suitable name for this factor could be:

"Social Media Engagement and Enjoyment in Learning"

The items in Factor 3 suggest a focus on comfort, skills, and positive attitudes towards using computers and web-based systems. A suitable name for this factor could be:

"Computer and Technology Comfort"

The items in Factor 4 suggest a focus on ease of use, organization, and clarity of the social media platform used for the course. A suitable name for this factor could be:

"Usability and Organization of Social Media for Learning"

Table 4. Factor analysis results for the Makel course taught via Microsoft Teams.

Items included in factor 1	*Factor loads*	*Factor 1- Reliability Analysis*
The newly acquired knowledge on the course confirmed and improved my pre-class knowledge.	0.866	0.924
I related what I learned in the units to the concepts I had learned in previous units.	0.862	
The assignments were instrumental in my learning the lesson better.	0.82	
The graphics and animations used in the lecture helped me learn.	0.787	
The mechanisms section of the course, which was taught through the Teams class, was useful.	0.764	
Feedback through the Teams class helped me learn.	0.744	
Additional documents related to the lesson shared in the Teams class allowed me to learn the lesson better.	0.644	
The class created in Microsoft Teams for the course was well organized.	0.638	
Items included in factor 2	***Factor loads***	***Factor 2 -Reliability Analysis***
I found the web-based training system useful	0.886	0.927
If I were to take the class again, I would want it to be taught in the Teams classroom again.	0.858	
The fact that the lesson was taught through the Teams classroom made learning fun.	0.82	
Working through the Teams classroom has helped me learn.	0.762	
I found the Teams class in which the lesson was taught interesting.	0.729	
Items included in factor 3	***Factor loads***	***Factor 3 -Reliability Analysis***
It was easy to use the Teams classroom that opened to teach the lesson.	0.90	0.823
It was easy to follow the instructions in the Teams classroom that opened for the course to be taught.	0.872	
I was able to follow both the course content and the announcements through the Teams class.	0.69	
I liked the overall structure of the Teams class in which the course was taught.	0.594	
Cronbach Alpha for all items		*0.933*

The items in Factor 1 suggest a focus on effective learning, integration of knowledge, and the use of additional resources in a well-structured Microsoft Teams environment. A suitable name for this factor could be:

"Organized and Resourceful Learning Environment in Teams"

The items in Factor 2 suggest a focus on positive perceptions, engagement, and the effectiveness of learning through the Microsoft Teams platform. A suitable name for this factor could be:

"Positive Learning Experience with Teams"

The items in Factor 3 suggest a focus on ease of use, navigation, and satisfaction with the structure of the Teams classroom. A suitable name for this factor could be:

"Usability and Structure of Teams Classroom"

7 CONCLUSION

This study examined the effectiveness of Facebook Classrooms and Microsoft Teams for online industrial design education in terms of students' and instructors' opinions, shedding light on how each platform enhances various aspects of the learning experience.

For Facebook Classrooms, the analysis revealed four key factors: Social Media-Driven Learning Support, Social Media Engagement and Enjoyment in Learning, Computer and Technology Comfort, and Usability and Organization of Social Media for Learning. These findings highlight how Facebook Classrooms enrich learning by offering opportunities for sharing, feedback, communication, and collaboration that students find valuable. The platform creates an enjoyable and engaging learning environment, making the process more fun and motivating. Its informal nature enhances the learning experience, making it more appealing to students. Additionally, students' familiarity with Facebook's well-known interface plays a significant role in their positive perception of the platform, as this facilitates an easier transition from its social media use to educational use, allowing students to navigate it effortlessly and access course materials with ease. Facebook Classrooms' connection to the outside world also encourages greater interaction, collaboration, and resource sharing among students, companies, and industrial design professionals, helping students feel connected and motivated.

For Microsoft Teams, the factor analysis revealed three main factors: Organized and Resourceful Learning Environment in Teams, Positive Learning Experience with Teams, and Usability and Structure of Teams Classroom. These results show that Microsoft Teams is appreciated for its structured and organized approach to delivering course content, making it easier for students to access learning materials and assignments. The platform also promotes a positive learning experience by fostering student engagement and interactivity. Although it requires a bit of getting used to, students value the intuitive interface and clear structure of

Teams, its ability to support various activities, including discussions, real-time feedback, and multimedia sharing, which enables them to follow the course content and announcements without difficulty.

Students and educators often have differing perspectives on the effectiveness and usability of digital learning platforms. During informal interviews with the students, it is seen that they generally prioritize ease of access, flexibility, and interactivity in online learning platforms. Many find Facebook Groups more engaging due to its informal, familiar interface and ability to facilitate peer-to-peer interaction. The social nature of the platform allows for quick discussions, collaborative problem-solving, and real-time feedback from classmates. However, students also reported concerns about distractions, lack of structure, and difficulty in tracking educational content, which can affect their learning experience.

Educators, on the other hand, tend to favor Microsoft Teams due to its structured, formal learning environment. According to them, it allows for better content organization, assessment tools, and controlled interactions, making it easier to manage coursework and maintain academic integrity. Educators also appreciate the ability to integrate other internal tools, such as file-sharing, quizzes, and scheduled meetings. However, some note that Teams may feel less engaging for students and lacks the social spontaneity that platforms like Facebook offer.

The key contrast lies in how each group perceives engagement versus structure. Students lean toward interactive and dynamic learning experiences, while educators value organization and control over course delivery.

Although Microsoft Teams seems to come forward as the winning learning management platform, the cost of using Facebook being zero almost evens up the competition in Facebook's favor, and this can even be a decision maker for institution management with smaller budgets.

In conclusion, both Facebook Classrooms and Microsoft Teams have proven to be effective platforms for online teaching in Makel lessons, offering unique strengths that enhance the learning experience. The pedagogical effects of using Learning Management Systems in industrial design education are evident in their ability to facilitate structured learning, support collaborative problem-solving, and enhance student engagement through organized content delivery and interactive feedback mechanisms. Looking ahead, institutions can combine Teams' structured approach with the creative flexibility of Facebook to create hybrid learning environments. Microsoft and Facebook also as firms, can develop their systems accordingly. Finding affordable ways to incorporate emerging technologies like AR/VR, 3D modeling tools, and AI-driven feedback systems can further enhance online industrial design education, ensuring its relevance and effectiveness in the post-pandemic era.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence (AI) tools. All content, including text, data analysis, and figures, was solely generated by the authors.

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