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Design of Moodle-based collaborative learning activities to enhance student interactions

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Abstract

Purpose – This article explores the impact of systematically designed online collaborative activities in two engineering undergraduate modules and key considerations for student interaction in Moodle.

Design/methodology/approach – The educational design research approach was chosen to improve educational practices through iterative needs analysis, design, development and implementation. The study followed design-based research (DBR) approach, with a mixed-method research design used to uncover the critical factors in designing, developing and implementing online collaborative learning activities for improving student interaction. Two iterative cycles of online collaborative learning activities were implemented using the Moodle learning management system for two modules of an engineering undergraduate degree programme at a state university in Sri Lanka.

Findings – Results indicate that students had demonstrated increased motivation for collaborative activities, and they had not experienced any significant difficulties in accessing materials or instructions. This study emphasizes that the design of learning activities has a greater influence on determining the level of interaction between the learner interface and the learner content. Also, a higher number of interactions on the wiki page improved learner-learner interactions, likely due to clear instructions and reduced complexities compared to previous Moodle activities. Overall, appropriately designed online activities can enhance students' motivation and improve communication, collaboration, cooperation and a sense of community among peers.

Research limitations/implications – The study's constraints included a small sample size of 93 students in two courses, which limits generalization of the results. The study's findings should be carefully considered before being applied to courses with nontechnical content. The second constraint was the number of courses on which the activities were carried out. The activities were designed specifically for two Earth Resources

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Data availability statement: The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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engineering courses, and the developed activities addressed technical course content. The effect of the activities on students' engagement and motivation in various courses with nontechnical content must be investigated, and a complete generalization of the study's results may be called into question. As a result, careful consideration must be given to generalizing the study's findings.

Practical implications – The study found that authentic collaborative learning activities using online technologies increased student participation and helped them discover their engineering design skills. Future research can focus on developing activities for other technical courses and incorporating additional tools into the instructional process. The use of a design-based research approach was recommended for future studies to obtain more comprehensive results than traditional comparative study designs.

Originality/value – The findings of this study suggest mechanisms to improve student interaction through online collaborative activities, particularly for delivering technical content. Such an understanding of learner interactions with course content, peers, teachers and interfaces will assist in the effective transformation of traditional technical content to online delivery mode. This is a unique study of converting in-class delivered engineering module content to online delivery within an equal time frame under restricted facilities and conditions resulting from a pandemic environment.

Keywords Moodle activity-design, Design-based research, Group work, Peer interactions, Online education, Content development research

Paper type Case study

Introduction

Social learning environments that involve interaction between students and teachers are typical in online courses, despite the fact that they happen individually or in isolation. According to (Hong *et al.*, 2021), students' engagement in academically meaningful activities is crucial. However, the level of interactivity can vary depending on the course design and the nature of the activities related to the module's content (Clark and Post, 2021). Course design is a critical factor in determining the quality and type of interaction, with instructor skills being essential for creating and managing interaction in online courses, particularly in a collaborative learning situation (Çebi and Güyer, 2020; De Backer *et al.*, 2022). Empowering students through choices, such as allowing them to choose their assignments' topics and formats, can be beneficial (e.g. traditional paper, video, project, product and model) (Lan, 2022).

Furthermore, students may have reservations about their involvement in group work conducted in online environments (Hanbidge *et al.*, 2020; Johar *et al.*, 2023). Conole (2013) defines learning design (LD) as "a methodology that enables teachers and designers to make more informed decisions regarding the design of learning activities and interventions that is pedagogically informed and makes effective use of appropriate resources and technologies" (Conole, 2013). "Learning Design" (LD) is concerned with "what students do" as part of their learning, as opposed to instruction, which is concerned with the delivery of content. There is a growing realisation that LD is a necessary component of learning (Giesbers *et al.*, 2014; Hernández-Leo *et al.*, 2014; Rienties and Toetenel, 2016). A user-oriented course design is prevalent in biology (Hester *et al.*, 2018; Malone *et al.*, 2018; Dewey *et al.*, 2022). However, there is a lack of substantial model-based engineering material for undergraduate students (Érdi, 2015).

Educational technologies are intended to enhance the teaching-learning process, especially in engineering education. Technologies like virtual labs/remote labs, immersive learning environments, machine learning and virtual assistants play a pivotal role. Hernandez-de-Menendez and Morales-Menendez (2019) analysed QS-ranked universities for engineering and technology in 2018 and found that the most commonly used learning tools are virtual environments (e.g. Second Life and World of Warcraft), educational games (e.g. Minecraft Education Edition and SimSE), web-based platforms (e.g. massive open online courses (MOOCs), single point of contact (SPOCs) and Intellipath), robots (e.g. LEGO Mindstorms NXT) and virtual labs/simulations (e.g. RobUAlab, Tecnologico de Monterrey

OLabs) for engineering education. Also, mobile devices are utilized for assignments, collaboration and fieldwork support. Further, teaching tools such as social networks (e.g. Facebook, Twitter and YouTube), web-based platforms (e.g. Ed Tech Rapid Cycle Evaluation Coach, TED-Ed, Curatr and Moodle) and Internet of Things (IoT) devices such as smart classroom environment devices, attendance systems, real-time feedback tools and analysis and assessment tools are also popular in engineering education. Furthermore, Sezgin and Cirak (2021) conducted a systematic analysis of MOOCs in engineering education, revealing the necessity for further studies to investigate the learning processes within domain-specific MOOCs to enhance learning opportunities in the field of engineering education. Additionally, Hernandez-de-Menendez *et al.* (2020) emphasize that preparing for Industry 4.0 in engineering education requires addressing curriculum content and competency requirements and incorporating relevant technologies. In this context, blended learning/online learning transformative course redesign is considered important (Horváth *et al.*, 2009; Clark and Post, 2021).

This article explores the impact of systematically designed online collaborative activities on student engagement using two engineering undergraduate modules. The content of this paper has been structured with literature on online collaborative learning, followed by an examination of the types of interactions prevalent among online learners. It follows the Moodle learning environment, delving into its significance and influence in the context of collaborative learning. The methodology section outlines the research design, participant selection, data collection methods and the intricacies of the DBR process employed in this study. The results gathered from the investigation and discussion offer insights into considerations when designing activities for the online group learning environment. This paper synthesizes the findings to provide valuable implications for educators, institutions and researchers involved in advancing online collaborative learning environments.

The available literature with regard to online collaborative learning can be considered under four separate segments for the convenience of understanding the respective backgrounds with scholarly evolution. This section consists of online collaborative learning, the types of interactions among online learners, the Moodle learning environment and Moodle course design with in-depth information relevant to the development of the research.

Online collaborative learning

"Collaborative learning" involves groups of students working together to find meaning, comprehension or solutions (Smith and Macgregor, 1992). This learning approach promotes in-depth learning within small teams through the voluntary sharing of high-quality content. Abuhassna and Alnawajha (2023a, 2023b) discovered that collaborative learning was the subject of discussion in 12% of the reviewed articles spanning from 2012 to 2022 (Abuhassna and Alnawajha, 2023a, b). The Gilly Salmon five-stage model (Salmon *et al.*, 2010) aims to enhance online learner interaction and participation by improving their skills and comfort levels. The framework emphasizes individual access and introduces learners to an online learning procedure in Stage 1. In Stage 2, participants create online personas and groups to collaborate during the course. Stage 3 involves exchanging information to develop mutuality, while Stage 4 discussions focus on working towards group goals. Finally, participants reflect on their learning journey to evaluate the benefits and goals achieved.

Collaborative learning activities, such as group discussions, tasks and games, can improve student interactions (Swid *et al.*, 2018; Jabbar and Hasmy, 2020). Online activities like field trips, case studies, simulations and discussions also enhance engagement (Zheng *et al.*, 2019; Jabbar and Hasmy, 2020). Technology's impact on student motivation and engagement must be analysed by educators and researchers (Koole, 2009; Krull and Duart, 2017; Gronseth *et al.*, 2020; Setiadi *et al.*, 2021; Lan, 2022). In order to close the gap in engineering education, the focus of this study was on designing and developing collaborative activities that would enhance the engagement level of engineering undergraduates.

Type of interactions among online learners

Learners who are distant, remote or online must understand the distinctions between four types of interactions: learner-content, learner-instructor, learner-learner and learner-interface (Moore, 1989). According to Siemens (2004), learner-learner interactions in an online learning environment can be further classified into four stages: communication (conversations and debates), collaboration (exchanging ideas and cooperating in a relaxed environment), collaboration (collaborating on works but with an individual agenda) and community (pursuing a common goal) (Siemens, 2004).

Regular student contact is essential for the development of a collaborative, student-centred environment conducive to the formation of a community of learners. While an instructor may combine many instructional technologies as seamlessly as possible into the learning management systems (LMS), rather than forcing students to learn and navigate between a variety of distinct platforms, indeed, directing students to multiple websites and resources can be confusing and disengaging. Teachers can research best practices for setting up and using collaborative applications or they can use the technology tools available in their LMS. The actions that they perform, such as continuing a thread, referring explicitly to others' messages, asking questions, complimenting, expressing appreciation and quoting from others' messages, can be used to monitor interactive behaviours. Hence, the objective of this study was to formulate online collaborative activities to investigate the factors influencing students' responses.

Moodle learning environment

There are 561 LMSs available globally for educational purposes, with Edmodo, Moodle, MOOCs and Google Classroom being the most commonly used and researched learning platforms from 2015 to 2020 (Al-Ajlan and Zedan, 2008; Singh, 2015; Setiadi *et al.*, 2021). Moodle is the world's top open-source LMS, is widely used in the academic community and offers active courses in many languages (Lawler, 2011; Deepak, 2017; Kerimbayev *et al.*, 2017; Altinpulluk and Kesim, 2021). More than 60% of articles discussing Moodle from 2015 to 2021 were in the science, technology, engineering and mathematics (STEM) field, with most research focusing on curriculum development, assessment and student success factors (Moodle, 2022; Gamage *et al.*, 2022). While Moodle is increasingly popular, there is a lack of research on collaborative learning, student engagement and four types of interactions in Moodle-based activities (Gamage *et al.*, 2022).

Moodle course design

Designing a Moodle course requires careful consideration of various methodologies and theories in order to create an effective learning environment. Researchers have investigated several approaches to designing online courses, each with advantages and applications. These methods include case studies (Alves *et al.*, 2012), the analysis, design, development, implementation and evaluation (ADDIE) model (Abuhassna *et al.*, 2021), the research and development (R&D) ten-phase model (Arianti *et al.*, 2020) and the social constructivist learning theory.

Furthermore, the DBR approach has been employed to investigate the integration of open educational practices (OEP) into the Sri Lankan school system (Karunanayaka and Naidu,

2017) and undergraduate education (Sandanayake *et al.*, 2021), utilizing the Moodle learning environment. Additionally, Dewantara and Dibia (2021) utilized DBR to elucidate the principles of blended learning design with a heutagogical approach through the e-ganesha Moodle platform for Indonesian language learning. Similarly, Rissanen and Saastamoinen (2018) employed DBR within Moodle to implement three courses in science and technology for the Department of Military Technology at the National Defence University, Helsinki. Moreover, Bourdeau (2017) used the DBR approach to launch the Educational Technologies and Teaching in Context (TEEC) project in Moodle, establishing it as a collaborative learning environment.

Further investigation of DBR in Moodle collaborative activities is needed for the knowledge contribution. The following questions seem to not be addressed in the existing literature:

(1) How do Moodle collaborative activities affect the level of engagement of undergraduate students?

(2) Is there any influence of Moodle learning activities on students' responses?

(3) What are the key factors to consider when designing Moodle-based collaborative learning activities?

To improve the understanding of the above, this study has developed the following methodology:

Methodology

In educational practice, design research is a systematic and adaptable process that aims to improve educational practices via iterative analysis of needs, design, development and implementation (Wang and Hannafin, 2011). In this study, educational design research was chosen as the primary research approach (Van den Akker *et al.*, 2006). Design experiments were created in order to conduct formative research and figure out what to do next. Educational designs were tested and refined using theoretical ideas as a guide. This study followed Reeves' DBR approach, with a mixed-methods research design used to uncover the critical factors in designing, developing and implementing online collaborative learning activities for improving student interaction (Amiel and Reeves, 2008; Hernandez-de-Menendez and Morales-Menendez, 2019). Two iterative cycles of online collaborative learning activities were implemented using the Moodle LMS for two modules of the Earth Resources Engineering undergraduate degree programme at a state university in Sri Lanka.

The experiment was designed and developed for the two modules on the Moodle platform. One module (M2–S2) was available to first-year Semester 2 students and the other module (M1–S8) was available to students in their final year of Semester 8. The activities were designed, developed and implemented with careful consideration for the student's level of study, with adequate monitoring and assistance as needed. As in the authors' previous study (Peramunugamage *et al.*, 2020a, b), the activities were designed using Gilly Salmon's five-stage model (Salmon *et al.*, 2010), with the tools used as indicated in the methodology.

Participants of the study

The participants chosen for the study's artefact implementation were final-year (Semester 8) and first-year (Semester 2) undergraduates who enrolled in the modules M1–S8 & M2–S2 during 2020–2021, with student numbers 48 and 59, respectively. The participant population consisted of a mix of male and female students aged 18–22 who were divided into groups of 4–5 members to carry out the activities in accordance with the content of the module outline.

The instructional procedure and amount of guidance were nearly identical for both courses, with the only difference being that the delivery methodology was changed from traditional to online collaborative learning. In addition to having two modules from the same specialization but studying at different levels, the lecturer in charge of the activities and the total number of direct contact hours for the course were the same in both courses.

Data collection instruments

To collect data on student interactions and participation in activities, three instruments were used: two online questionnaire surveys, focused group discussions and Moodle log records. The online questionnaire was administered at the middle and end of the semester in order to investigate the impact of the activities on learning the module content. Purposive sampling was used to select the sample size for questionnaire distribution. In cases where the population size is restricted and the researcher is assured that the target population sufficiently fulfils the study's requirements, "Purposive Sampling" stands out as the optimal approach. This technique guarantees that the chosen participants are ideally suited to the study (Robinson, 2014; Campbell *et al.*, 2020). The survey contained 30 questions divided into four sections: course content and organisation, feedback and assessment, Moodle access and learning resources. Feedback from the first course's activities (M1–S8) was used to make necessary changes to the online Moodle-based activities before they were re-implemented in the second course (M2–S2).

The "action logs" served as a means to gather feedback on resources and activities accessed by the learners, capturing details such as when, by which student and for how long. In the scope of this study, comprehensive logs documenting students' actions throughout the entire semester for each module were collected and meticulously cleaned. Each entry in the raw action log comprises nine attributes: time, user full name, affected user, event context, component, event name, description, origin and IP address. These attributes collectively provide a detailed and structured account of the interactions within the learning environment, facilitating a thorough analysis of student engagement and participation.

Online-focus group discussions

To assess motivation and engagement, Zoom was used to facilitate online group discussions that were specifically geared towards responding to the research questions. The ethics review committee of tThe Open University of Sri Lanka (OUSL) validated the questions' credibility. Additionally, four students from the same course were asked to pilot the interview questions, and their responses were excluded from the primary interviews. The interview protocol consisted of questions about students' viewpoints on (1) the acquisition of networking concepts through activities, (2) the impact of activities on learners' attitudes towards course content and (3) similarities and differences between this course and other courses without activities. Each focus group consisted of three students interviewed via the Zoom platform. All group members engaged in discussions, answering, elaborating and commenting on one another's responses. The interview protocol was administered to 16 and 15 students, respectively, out of 48 and 59 students.

Iterative cycles of activity design and implementation

DBR-cycle 1, phase 1 – identifying the learning problem

The study began with a review of existing literature and preliminary fact-finding studies involving lecturers and students. As class size increases, student interactions and collaborations may decrease, which can make students feel uneasy about performing well and completing tasks. The learning problem of "how to use Moodle tools to enhance student interactions?" was studied from M1–S8 over a 14-week period that included face-to-face and two-hour practical sessions. The final grade includes 30% from continuous assessments and 70% from the end-of-semester exam. However, due to the pandemic, the module was completed entirely online, with students using computers or smart devices. The final grade included continuous assessments and an end-of-semester exam. The average demographics of 80% males and 20% females were distributed across the country with varying levels of connectivity.

DBR-cycle 1, phase 2 – designing collaborative activities

In the second stage of the study, the focus was on developing instructional tools that address theoretical and practical aspects of the learning problem. The goal was to create Moodle-based collaborative activities that improve the student's interaction with the teacher, students, content and interface while staying true to the intended content. Table 1 illustrates the first activities designed and implemented for M1–S8. Managing technology should not be a significant challenge for students who are already familiar with the Moodle environment. Group activities included wiki, forums, chats and workshops, with groups consisting of 4–5 students or 10–12 students in virtual lab sessions. When designing online collaborative activities, teachers should consider subject matter, learners and technology/tools. The Gilly Salmon five-stage

Week	Phase	Collaborative learning activity	Interaction type
1–2	Stage 1 Access and motivation	*Journal (2)–* 1. Read Chapter 5 of the Environmental Education book, identify the waste treatment technologies and create a summary of one page 2. Read the given reading materials and watch the video, identify the types of mine wastes then create a summary of one page	LC LI
2–3	Stage 2 Online socialization	*Forum discussion–* Join the webinar on Sustainable Technologies, participate actively, share your experience on the webinar with peers in the forum and constructively comment on at least two other posts on the forum	LC, LI LL, LT
4–5	Stage 3 Information exchange	*Creating Wiki (3)–* Students are assigned to 4 member groups to perform an assignment on a case study, tasks were revealed weekly where a final submission is required at the end, each week 2 questions were given to create the wiki based on the assigned mining site	LC, LI LL, LT
7–9	Stage 4 Knowledge construction	*Virtual Lab (2)–* 1. Water analysis – To determine the physical parameters students have to perform the given activities based on the samples and answer the questionnaire 2. Water quality analysis – To determine the chemical parameters students have to perform the given activities based on the samples and answer a questionnaire	LC, LI LL, LT
10–13	Stage 5 Development	*Workshop –* Submit the sustainable development plan for the assigned mining site and evaluate two other submissions from other submissions. Evaluation criteria provided as a rubric	LC, LI LL, LT

Note(s): LL –learner-learner interaction; LT – learner-teacher interaction
LC – learner-content interaction; LI – learner-interface interaction
Source(s): Table by authors

Table 1. Activity design for module M1–S8 according to the Gilly Salmon five-stage model

approach was used to improve engagement and participation in the blended classroom setting, with Moodle-based activities designed to meet the course's learning objectives.

DBR-cycle 1, phase 3 – testing the collaborative activities

During the third phase, the instructional tools were tested in classrooms and modifications were made based on student feedback, as shown in Table 2. The activities were provided through Moodle, and students completed them after covering course content via Zoom or other materials. The activities had deadlines and students worked together in groups to complete them. They distributed materials, created content and discussed their work before submitting a final answer. Teachers provided feedback on the materials submitted by students to assess their understanding of the concepts and topics.

DBR-cycle 1, phase 4 – evaluating the collaborative activities

The fourth stage involves evaluating the effectiveness of the instructional tools by examining the evidence of student learning, as stated by Barab and Squire (2004), Anderson and Shattuck (2012). The student's engagement with the forum, wiki, workshop activities and log records was observed to determine their involvement in the activities, and their performance was graded regularly. Based on the feedback and log records, improvements and adjustments were made to the online collaborative activities. For instance, during the activities, students expressed a desire for more detailed feedback and the teacher responded by providing feedback while they were still working on the activities or soon after completing them. Additionally, the teacher conducted online Zoom meetings with group members who required further clarification, and they were given extra time to revise their responses based on the feedback received.

(1) Multi-point assessment criteria were used to evaluate students, and they were given enough attempts to complete all components.

(2) Students indicated the need for more explanations and examples for each activity. Consequently, sample videos, online sessions and guidelines were incorporated into each activity in the second module.

(3) Some of the activity steps were simplified and revised. The instructions were made clear, concise and easy to follow.

Table 2.
Changes to the activity design in cycle 2

Learning activity	Observation	Changes to the activity design
Journal (2)	First activity 23/44 submissions Second activity 39/44 submissions	Activity completion time extended, More instructions
Forum discussion	4 discussions	At the beginning of the course introduce the activity
Creating Wiki (3)	A single participant has altered the wiki	Clear instruction and allow marks for each contribution
Virtual Lab	Actively participated	
Workshop	Participation (100%) Peer evaluation (75%)	More instructions and hands-on experience in workshop activities

Source(s): Table by authors

Data were collected through pre- and post-semester questionnaires and focused group interviews to determine the impact of instructional methods and activities on student participation and interactions. Additionally, Moodle log records were examined and weekly interviews were conducted with students in the second semester.

DBR-cycle 1, phase 5 – reflecting on the collaborative activities and their implementation
The final stage involves a retrospective analysis that addresses the methodology's epistemic commitments. Reflecting on practical outcomes entails contextualizing any learning gains within the context of the learning ecology. This reflection enabled us to determine whether certain aspects of the instructional tools were more effective at supporting learning than others.

The following design principles could be derived from the first cycle of DBR outcomes:

(1) Further familiarization with Moodle activities such as a forum, wiki and workshop to support students using them without hesitation using technology.

(2) Redesigning activities to motivate student engagement.

(3) Teacher feedback with continuous monitoring and guidelines.

(4) Inter-connected activities could increase student participation and evaluation.

The second cycle (cycle 2) was started with redesigned activities based on the above observations.

DBR-cycle 2, phase 1 – redesign and refine (redesigning the learning activities)
Sandoval (2014) articulated the final "epistemic commitment" as an iterative process of continually refining instructional tools based on evidence of student learning to produce more robust learning environments. DBRs recognise the difficulty in accounting for all variables that could impact student learning or the implementation of instructional tools *a priori* by viewing educational inquiry as formative research (Collins *et al.*, 2009). Robust instructional designs are the result of trial and error, which is reinforced by a systematic analysis of how they perform in real-world situations.

Module 2 (M2–S2) activities have been redesigned in light of the module 1 (M1–S8) experience (Cycle 1 Stage 5). The activity list is shown in Appendix. This is also a compulsory module for Semester 2 (first-year) students in the same specialization as in the previous instance. The module (14 weeks) consists of a weekly 1-h face-to-face lecture and a two-hour practical session in which students work in small groups to complete workshop activities. Evaluation proportions included 60% for the continuous assessments and 40% for the end-semester (written) examination. However, due to COVID-19, this module was also completely conducted online amidst the challenges of delivering the workshop components. Classes are generally composed of the following demographics: 80% of males and20% of females, and everyone owns a mobile smart device.

Data analysis and results

Data collection involved two online questionnaires administered at the beginning and end of each course via Moodle, along with log records and focused group interviews to gather students' perspectives. Data analysis was conducted in three stages: quantitative analysis, log record analysis and thematic analysis of interview data. The Likert scale [1-strongly disagree, 2-strongly disagree, 3-disagree, 4-agree and 5-strongly agree] was used to assess students' familiarity and agreement with each item, and the first questionnaire was given during the fourth week of the course, while the second was distributed at the end of the course.

Analysis based on questionnaires

About 30 questions were categorized into four sections, with learners providing feedback on course content and organization, feedback and assessment, Moodle access and teacher feedback and learning resources. A five-point Likert scale was used, with ratings weighted from 1 to 5 [5 for "Strongly Agree," 4 for "Agree," 3 for "Neutral," 2 for "Disagree" and 1 for "Strongly Disagree]. The first module received 45 out of 48 responses, and the second module received 49 out of 59 responses. Overall, both modules received highly positive ratings, with mean responses exceeding 3.5. Despite the transition to fully online delivery and assessments, learners were motivated and engaged in the online activities. The second module, in particular, was challenging for first-year students, but they overcame pandemic-related challenges and remained motivated.

Additionally, students completed a second questionnaire regarding their online collaborative experience on Wiki, journal, forum and assignment tools on Moodle, motivation and attitude towards group activities, which included Likert scale items ranging from 5-Strongly Agree to 4-Agree, 3-Neutral, 2-Disagree, and 1-Strongly Disagree. The mean was determined using the five-point Likert scale. The results for statements were framed in positive terms, with learners strongly agreeing and mean responses greater than three. Table 3 shows the mean responses for Moodle collaborative activities. There were 35 responses from students enrolled in Module 1 and 45 responses from students enrolled in Module 2.

Furthermore, students were asked to rate their frequency of access to online activities on a scale of 1–4, with 1 representing never, 2 – one to five times, 3 –five to ten times and 4 – more than ten times. Results indicated that students generally participated in collaborative

	Wiki		Journal		Forum		Assignments	
	Module 1	Module 2	Module 1	Module 2	Module 1	Module 2	Module 1	Module 2
1. Wiki/Journal/Forum/ Assignments motivated me to actively participate and interact with colleagues	4.0625	3.8000	4.1471	3.8889	4.0588	3.9556	4.4706	4.0222
2. I could access content and resources through Wiki/Journal/Forum/ Assignments	4.1250	3.9111	4.1471	4.0000	4.1471	4.0667	4.3824	4.1333
3. Peer interactions are promoted through Wiki/ Journal/Forum/ Assignments	4.0000	3.8000	4.0294	3.8222	4.2059	3.9556	4.1765	3.9778
4. Wiki/Journal/Forum/ Assignments create opportunities to generate, present and disseminate knowledge	4.0625	3.8667	4.2353	3.8667	4.1176	4.1111	4.2647	4.0000

Source(s): Table by authors

Table 3.
Feedback on online collaborative activities

activities one to five times per week, even though these activities were not mandatory to complete. This indicates student motivation to engage with learning resources and activities, which in turn would help them meet the course learning outcomes.

Analysis based on Moodle log records

Moodle's log records provide valuable feedback for content developers and instructional designers. The study collected and cleaned logs of students' actions for the entire semester for each course. The focus was on the user's full name, component and event name attributes. These attributes represent actions initiated by students on various Moodle items such as assignments, quizzes, assessments, course content, forum discussions, wikis, workshops, resources and URLs. The study only considered attributes related to student interactions with forums, workshops and wikis. For Module 1, there were 330,081 actions and for Module 2, there were 593,791 actions available for analysis.

Romero *et al.* (2008) described the data mining process, which was implemented in two phases. Initially, data preparation was performed to ensure that the information was suitable for further analysis. Data mining algorithms were then used to transform the prepared data into a format that could be interpreted and analysed. After normalising the data from the two modules, the aggregate counts for each action type across the two modules were computed. To facilitate this process, the R programming language was used, which allowed for the categorization of all action logs related to collaborative activities. The normalized data showed that students in Module 1 accessed Moodle primarily for assessments, while Module 2 students had more interaction with instructional materials, Zoom sessions and assessments. Visualizations of the data may help course administrators plan strategic interventions to maintain engagement with learning objectives. In Module 2, there was a significant increase in collaborative work participation, with Wiki page views increasing from 2.0% to 6.2%, Wiki pages updated increasing from 0.8% to 1.1%, comments viewed increasing from 0.3% to 1.8%, discussions created increasing from <0.1% to 0.2% and discussions viewed increasing from 0.4% to 1.7%. Moodle promotes student-content interaction as well as learner-teacher and learner-learner interactions and can foster group work, group cohesiveness, discussion and information transfer in a technology-mediated setting.

Analysis based on interview data

Thematic analysis was employed for the analysis of interview data. Six sub-themes emerged: "Convenience", "Internet access", "Use of Moodle Tools", "Accessing Resources", "Peer Support" and "Support from the teacher." These sub-themes were categorized into two overarching themes: Technological matters, emphasizing students' use of hardware and software for both synchronous and asynchronous learning, highlighting the significance of technological infrastructure and pedagogical matters, focusing on delivery methods, learning material presentation, time allocation, pace and diverse approaches to enhance engagement, emphasizing the instructional aspect of learning.

Discussion and conclusion

Initially, this study investigated the impact of Moodle collaborative activities on undergraduate student engagement. Analysis of Moodle log records revealed that participation in online collaborative learning environments enhances interactions in learner-learner, learner-teacher, learner-content and learner-interface dynamics. Additionally, iterative content development and instructional process redesign significantly contributed to heightened engagement through the Moodle platform. Questionnaire results indicated seamless access to materials and instructions, with no issues reported during online interviews. Students appreciated the convenience of resource access and the support from both peers and teachers. In contrast (Jabbar and Hasmy, 2020) discovered difficulties in SEUSL students collaborating through Moodle, with many unaware of its collaborative tools. This study underscores the pivotal role of learning activity design in shaping the interaction between the learner interface and learner content.

This study found that online collaborative learning improved student engagement with peers and teachers and provided greater flexibility in terms of time and location. Material sharing was also facilitated through various applications. Students found the online activities to be effective in managing the shift to COVID-19 and in deepening their understanding and retention of course content. This study's findings agreed with those of (Hashim *et al.*, 2015) in terms of m-learning's impact on personal fulfilment. However, it was noted that first-year students may require more time and opportunities to develop a sense of community and enhance their collaborative learning skills. The first research question was successfully addressed, demonstrating the positive impact of online collaborative activities on student engagement.

Secondly, the research aimed to investigate whether Moodle learning activities influenced students' responses. Increased interactions on the wiki page positively affected learner-learner interactions, likely due to clear instructions and addressing previous implementation issues. Well-designed online activities have the potential to boost students' motivation and improve communication, collaboration, cooperation and a sense of community among peers (Ong and Quek, 2023). However, accessing online activities and providing feedback to colleagues was below average, possibly due to a lack of experience with online interactions and pandemic-related shifts in learning environments. Questionnaire findings showed that implementing online activities positively impacted students' motivation to engage in collaborative work with their peers as well as supporting the creation and dissemination of knowledge among peers.

Finally, the research shifted its focus to identifying key considerations in designing Moodle-based collaborative learning activities. The online questionnaires showed an increase in motivation for collaborative activities, similar to previous studies by the authors (De Silva and Peramunugamage, 2023). Collaborative activities were worth less than 2% of students' overall scores, and the authentic problem-solving approach was similar to that of (Jones *et al.*, 2013). Also, interview findings emphasized that clear instructions facilitated collaboration and idea-sharing, while progress tracking and timely feedback improved interaction between teachers and students. The study addressed the third research question, emphasizing the importance of considering the duration of online collaborative activities and providing tailored feedback to students' academic levels during the design phase.

During the pandemic, designing and implementing online collaborative learning activities for two different courses in the same engineering undergraduate programme was challenging for both facilitators and students. However, the opportunity was utilized to experiment and improve learning methods suitable for the new environment. Findings indicate that Moodle collaborative activities have a greater impact on student learning during a pandemic than traditional activities. Such activities can enhance learner interaction with course content, peers, teachers and interfaces. These findings suggest ways to improve student interaction through online collaborative activities, particularly for technical content.

Recommendations for further research and limitations of the study

The study found that authentic collaborative learning activities using online technologies increased student participation and helped them discover their engineering design skills.

Future research can focus on developing activities for other technical courses and incorporating additional tools into the instructional process. The use of a design-based research approach was recommended for future studies to obtain more comprehensive results than traditional comparative study designs. Additionally, future research efforts can leverage these findings to enhance and broaden the design of Moodle collaborative activities. This will contribute to a more comprehensive understanding of the implications and effectiveness of collaborative activities within the context of Moodle-based learning, ensuring a robust foundation for future educational practices. Furthermore, future research should delve deeper into data analytics, specifically concentrating on comprehending online interactions within specific contexts. Identifying the challenges that organizations may face when adopting these innovative technologies is crucial. Moreover, the evolving landscape of machine learning and artificial intelligence is significantly influencing the utilization of ICTs, especially within the field of education. Therefore, researchers should prioritize adopting these new innovative technologies with a focus on fostering effective learning environments.

The study's constraints included a small sample size of 93 students in two courses, which limits the generalization of the results. The study's findings should be carefully considered before being applied to courses with nontechnical content. The second constraint was the number of courses on which the activities were carried out. The activities were designed specifically for two Earth Resources engineering courses and the developed activities addressed technical course content. The effect of the activities on students' engagement and motivation in various courses with nontechnical content must be investigated and a complete generalization of the study's results may be called into question. As a result, careful consideration must be given to generalizing the study's findings.

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(The Appendix follows overleaf)

Appendix

Activity	M1-S8 (n = 48) Total activities	M2-S2 (n = 59) Total activities	Interaction type
Online face-to-face sessions			
Zoom meeting	4	15	LT, LL
Seminar	1	0	LT, LL
webinar	1	0	LT, LL
Learning resources			
File reading material	10	5	LC
File additional resource video	6	8	LC
URL additional resources	5	0	LC
Lecture materials	2	11	LC
Recorded lectures/labs	2	8	LC
Tutorial	1	0	LC
Tutorial answers	1	0	LC
Coursework template	1	0	LC
Online Moodle tools used for activities			
Forum	2	4	LT, LL
Journal	2	0	LT
Virtual Lab	3	0	LT, LL, LC
Questionnaire	3	1	LC
Wiki	4	1	LT, LL
Workshop	1	2	LT, LL
Assignment	0	2	LT, LL
Turnitin assignment	4	1	LT, LL
Quiz	0	2	LC
Questionnaire – feedback	2	3	LC
	55	63	

Source(s): Table by authors

Table A1. Number of activities conducted for each course

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