

Article

A Framework of Implementing Strategies for Active Student Engagement in Remote/Online Teaching and Learning during the COVID-19 Pandemic

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Abstract: The COVID-19 pandemic has caused a drastic shift of face-to-face teaching and learning to remote/online teaching and learning at all levels of education worldwide. Active student engagement is always a challenging task for educators regardless of the teaching modalities. The degree of challenge for active student engagement increases significantly in remote/online teaching and learning. This paper presents a framework that implements activities/strategies to ensure active student engagement in remote/online teaching and learning during this COVID-19 pandemic. The structure of the developed framework combines the balanced use of adjusted teaching pedagogy, educational technologies, and an e-learning management system. Teaching pedagogy involves various active learning techniques, synchronous teaching, asynchronous teaching, and segmentation. The educational technologies, such as Google Meet, Jamboard, Google Chat, Breakout room, Mentimeter, Moodle, electronic writing devices, etc., enable the developed framework for active student engagement. An e-learning management system, Moodle, is used for course management purposes. Over the last three semesters (Fall 2020, Spring 2021, and Summer 2021), the framework is tested for three different engineering courses. A questionnaire draws out student perception on the developed framework in terms of active student engagement that ensures student–student interactions, student–instructor interactions, social presence, reinforces learning and deepens understanding of the materials in remote teaching. The feedback also indicates that combining the utilized technologies, synchronous teaching, and active learning activities in the developed framework is effective for interactive learning; hence a practical approach for active student engagement in remote/online teaching and learning. The article focuses on contributing to present research and infusing future research direction about technology-enhanced active student engagement in Engineering Education.

Keywords: active student engagement; active learning activities; remote teaching and learning; education technology; Moodle; COVID-19



Citation: Ahshan, R. A Framework of Implementing Strategies for Active Student Engagement in Remote/Online Teaching and Learning during the COVID-19 Pandemic. *Educ. Sci.* **2021**, *11*, 483. <https://doi.org/10.3390/educsci11090483>

Academic Editors: Maria Meletiou-Mavrotheris, Konstantinos Katzis, Angelos Sofianidis, Nayia Stylianidou and Panagiota Konstantinou-Katzi

Received: 5 August 2021

Accepted: 25 August 2021

Published: 31 August 2021

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1. Introduction

In history, a radical change in traditional teaching and learning at all levels of education occurs in March 2020 because of the ongoing COVID-19 epidemic. The revolutionary shift was from conventional Face-to-Face (F2F) teaching and learning to Emergency Remote Teaching and Learning (ERTL), later named Remote Teaching and Learning (RTL), which takes the form of online teaching and learning. However, online teaching and learning is not a radical shift but a practicing format of teaching and learning activities, not on a massive scale or at all levels. By the end of Fall 2018, about 35% of 17 million undergraduate students in 2-year and 4-year college programs were carrying out courses online. In postbaccalaureate, this was 40% of 3 million students [1]. Such a percentage of student enrollment in online teaching and learning has suddenly increased at all educational levels since March 2020 due to the COVID-19 situation.

Online education provides several advantages, such as accessing courses remotely, attending classes from anywhere, carrying out course work at own time and pace, re-

visiting course materials, and accommodating large classes, if the instruction mode is asynchronous [1,2]. Online teaching generally involves courses specifically designed and developed to conduct online, whereas RTL deals with courses primarily created, developed, and taught in the F2F method; however, they are now offered online [3]. The functional elements of RTL can be adopted from F2F and online education, as shown in Figure 1 [1]. Regardless of the teaching and learning format, the instructors and learners may face many difficulties while conducting courses. Some of the challenges are distractions in the learning environment, lack of social interactions, technical limitations, lack of active student engagement, motivation, no mechanism to identify slow learners, critical thinking, minimize unauthorized collaboration, fairness in evaluation, lack of technological skills, and time management, etc. [4–10]. Many of these challenges, such as social presence, active student engagement, student motivation, student-unauthorized collaboration, are easy to tackle in the F2F mode of instruction. However, such challenges raised significantly in RTL because of a drastic change in teaching and learning approaches requiring logistic and technical support and soft and hard skills for both the instructor and learners [7,10,11].

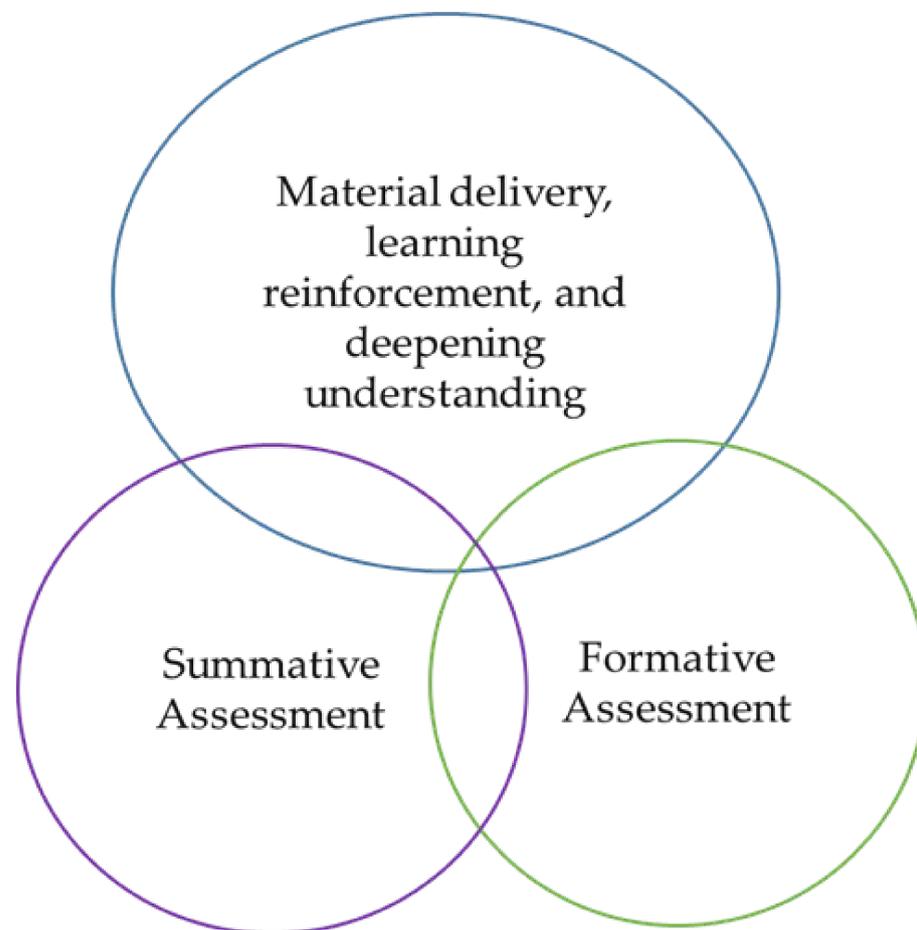


Figure 1. Functional elements of remote teaching and learning adopted from F2F teaching and learning.

Moreover, technology and communication infrastructure play a vital role in implementing and practicing the functional elements of the RTL [9,12]. Nevertheless, the core functional element of the RTL, material delivery, learning reinforcement, and deepening understanding, remains the fundamental challenge for the instructor towards accomplishing the course conduction [13,14]. This functional element of RTL is connected to technology learning, active learning activities, teaching pedagogy, and a course management system. These need to either learn or embrace from the experience of the F2F modality for active student engagement during RTL [1,15,16]. While active student engagement

is a great challenge, in general, the drastic shift of teaching and learning modality from F2F to RTL has added a new dimension to this challenge. Therefore, this study presents a framework that combines the available technology, teaching pedagogies, active learning activities, and course management system to implement the material delivery mechanism, communication with learners, learning reinforcement, deepening understanding during RTL. The suitability of this framework of active student engagement in RTL is examined and presented in this study. Therefore, the objectives of this study are:

- To develop a framework that ensures active student engagement during remote teaching and learning;
- To implement the active student engagement framework using active learning techniques, adjustable teaching pedagogy, and easily accessible educational technologies for engineering courses.

Accomplishing these objectives allows making following contributions:

1. The development of an active student engagement framework for remote teaching and learning during and post COVID-19 epidemic;
2. The performance evaluation of the active student engagement framework applied for engineering courses at different levels of an engineering program.

The rest of the paper has four sections. Section 2 presents a review of active student engagement strategies, leading to the research gap this study addressed. Section 3 describes the methodology that includes active student engagement framework development, implementation, and evaluation process. Section 4 presents results and a discussion of the results. Section 5 summarizes the paper, including the research limitation and future direction.

2. Related Work

Active student engagement is a critical factor that significantly influences students' learning and deepening understanding during online education. Student engagement is considered one of the functional elements in the CARE (Conceptualise, Activate, Reflect, and Engagement) learning design framework. The CARE methodology is designed as the refugee-responsive pedagogy that ensures student-driven teaching and learning [17]. The researchers in [18] illustrate two essential skills for sustainable education: responsibility and co-responsibility in light of the COVID-19 pandemic. Student engagement or dialogue can enhance such skills and values to contribute to society and profession with a positive mindset.

Student interactions online are classified as student–content interactions, student–teacher interactions, and student–student interactions, providing active student engagement in online teaching and learning [19]. Student–Content (SC) interactions allow students to work on interactive tutorials or simulations. Student–Instructor (SI) interactions enable students to work with the instructor either during synchronous teaching or through instructor-initiated discussion online or offline. Student–Student (SS) interactions help students work with their peers through group activities, participate in a discussion forum, and conduct laboratory experiments in a group. Researchers in [20–24] have shown a remarkable connection between these interactions and learners' satisfaction and learning outcomes for online education. Studies in [25,26] reveal that SS interactions make students feel they are actual classmates in virtual worlds, and SI interactions provide feelings that their instructors are real people. SS and SI interactions also enlighten positive outcomes on students' motivation, learning performance, satisfaction with instructor and courses, and pursuing studies consistently in online education [27–30]. It can be concluded that SS and SI interactions minimize isolation among the peers and between the learners and instructors in online education. Exercising such interactions in RTL can ensure active student engagement and enhance students' learning.

Synchronous and asynchronous are two forms of teaching methods for online education. Asynchronous teaching creates a learning environment engaging participants with the course materials at different times and locations [31]. It offers flexibility to the students

to learn at their own time and pace, enough time to develop understanding and comprehensive thinking and enhanced higher cognitive learning [32,33]. The significant challenges in the asynchronous teaching method are lack of social presence and verbal communication, the time lag in instructor feedback, requiring self-motivated learners, and inability to be organized without instructor contact [34–36]. On the other hand, synchronous teaching creates a learning environment that engages all participants with the course materials at the same time and space [31]. This teaching method offers live interaction between the students and instructors, enhanced communication efficacy, immediate feedback through live discussion, building social presences, and decision-making efficiency [37–40]. It can be concluded that online synchronous teaching can facilitate active engagement and increase interactions among the participants. However, can only synchronous instruction provide active student engagement? What other activities do the instructors need to care about for better active student engagement in RTL and effectively implement them?

Active learning techniques or activities effectively engage learners in thinking and doing things through different learning processes. It promotes higher-order thinking, cooperative and interactive learning, and problem-based learning [41]. The author in [42] has investigated the active learning approach for engineering courses, such as electronics and power electronics, which helps students' more profound understanding. Different active learning activities, such as in-class pre-work talk, summary discussion, and off-site preparation, are designed in a model-based learning approach. Researchers in [43,44] have found positive impacts of using active learning techniques in engineering courses. Such influences include deepening students' understanding, correlating theory and practical, gaining social interactions, and examining ideas. Active learning also allows formative assessment with feedback, which opens the eyes for the learners about their mistakes and learn from them [45]. The peer-review active learning approach applied for undergraduate and graduate courses. The study reveals that a guided peer review can provide evaluation scores close to the instructor evaluation and enhance the students' performance [46]. Problem-based and student-centered learning approaches combine experiential learning that improves students' performance and critical thinking for an engineering course, as indicated in [47].

Active learning techniques applied to computer science courses reveal students' perception of satisfactory feelings in learning course materials, being motivational, and feelings of proficiency of course content [48]. Interactive learning employed in business management courses for engineers shows improved learning experiences. It increased interest in the subject matter for the students, compared to the traditional teaching and learning approach [49]. In [50], the author applies an active learning approach for an electric drives control course to enhance students' problem-solving abilities. Active learning strategies used in a software modeling course exhibit mixed perceptions among the learners [51], such as some students show negative responses while others like the approach. It also claimed the difficulties faced by the instructors in implementing the learning strategies. Research unfolds the improvement in student performance after deploying active learning techniques in engineering courses [52]. A study examines performances of activity-based instructional design for a digital logic course using Moodle in [53], which indicates good acceptance of the instructional approach by the students and improved performances of the students' learning. The author in [54] presents a lecture-free active distance learning framework for an engineering course, embedded system. The study shows the students were highly engaged and satisfied with the instructional method; however, the student survey suggests including some lectures that would enhance their understanding better. Past research indicates that the deployment of active learning activities or techniques is welcoming and a new trend of teaching pedagogy. Such activities in the instructional approach can improve student engagement, increase their satisfaction, and enhance learning affairs, course learning outcomes, and overall student performance. However, the instructor needs considerable effort in planning and executing the teaching and learning process, particularly during the ERTL or RTL.

Active student engagement can be fostered using interactive teaching and learning approaches, learners' interactions ideas, active learning activities, and adaptive pedagogies for engineering courses. Most of the past research dealt with implementing these strategies/activities for the F2F teaching modality, while a few researchers implement them for ERTL/RTL modality. Moreover, planning and exercising any of these techniques or approaches and activities in ERTL/RTL requires significant learning and utilization of technologies. Technology learning requires for both the teacher and the learners. The recommendations and investigation of implementing active learning techniques for well-designed online or F2F courses are clearly stated in the literature; however, implementation techniques for engaging students actively in RTL are just a few. Moreover, the frequency and quality of interactions are a matter of engaging students actively in RTL. Therefore, this study addresses the following research questions:

1. Can online student interactions (SS and ST) engage students actively in RTL?;
2. Can synchronous teaching enhance active student engagement in RTL?;
3. Can active learning activities increase student engagement in RTL?;
4. How to implement online student interactions, synchronous teaching, and active learning activities in RTL?

3. Methodology

3.1. Framework of Active Student Engagement

Active student engagement in remote teaching requires lesson planning, redesigning instructional materials and activities during course conduction, selecting a teaching approach, technology learning, continuous students' feedback, and being ready for a correction. Figure 2 shows the framework for active student engagement during remote teaching. The author practiced this framework over the last three semesters (Fall 2020, Spring 2021, and Summer 2021) for three different engineering courses, such as Circuit Analysis I, Electrical Engineering Fundamentals, and Electrical Machines during the COVID-19 pandemic.

The framework starts with the lesson bridging and welcome message. The cheerful welcome message attracts students' attention at the beginning of the lesson. A lesson bridging is essential to connect between the classes. The visual lesson bridging can attract students better than the oral demonstrations. Afterward, ConcepTest is employed to assess students' understanding of a particular subject matter. The CocepTest activity requires design depending on whether the subject matter is already discussed (old) or planned (new). This activity helps the students deepen their understanding of the already discussed material and reflect on their knowledge. In the case of already discussed material, if the CocepTest appears satisfactory, the instructor can move to the next step. Otherwise, the instructor or a peer student initiates the further discussion. ConcepTest allows SC, SS, and SI interactions, which are crucial for active student engagement.

The following step is to define the learning objectives of the current lesson. The learning objective is to be designed based on the actions verbs according to the Bloom Taxonomy. Relating learning objectives with the program outcomes and graduate attributes is the key to engage them. Without relating to the graduate attributes, the learning objectives seem to be only theoretical. Subsequently, new materials are introduced for a segment of 10–20 min. Material delivery leads to a live discussion between the students and instructors, which ensures SI interactions. The instructor frequently invites students to respond to the specific questions raised by the instructor or a peer student. Then, the material delivery continues for another segment of ~15 min. This segment of material delivery leads to an activity called think-pair-share, where students are involved in doing things individually or in a pair. The instructor can easily monitor the students' work and discuss with the specific students whenever needed. This activity provides SI interactions with immediate feedback on learners' understanding.

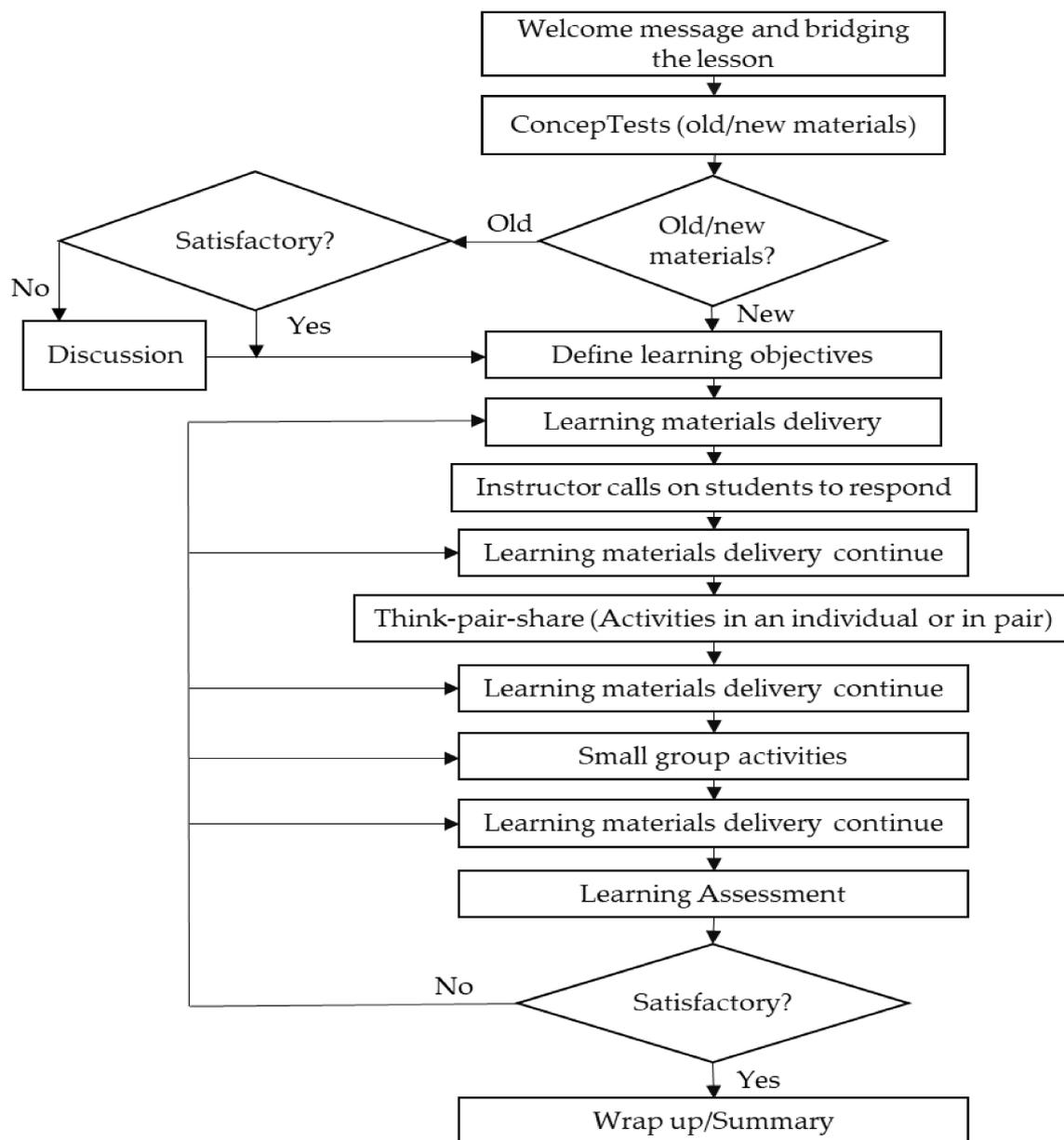


Figure 2. A layout of practicing active student engagement activities during material delivery, learning reinforcement, deepening understanding, and summative assessment.

The learning material delivery continues for another segment of 10–15 min. A small group discussion activity followed by this segment of material delivery is employed in the proposed framework. This group activity involves 4–5 students discussing a particular topic or solving a specific problem assigned by the instructor. The instructor acts as a facilitator and works with all small groups. The outcome of each group is shared with other groups and commented on by the peers whenever is needed.

Finally, the learning materials delivery continues for another short segment of up to 10 min. This segment of discussion can be even shorter that depends upon the instructor. The proposed framework also includes a learning assessment activity to assess students' understanding of the discussed materials. The learning assessment design is vital to identify the depth of learners' knowledge in the covered course contents. The learning assessment activities can be based on assigning a problem to solve, a quick test on a conceptual topic based on multiple-choice type questions, or asking students to outline key points that the learner learned. Based on the feedback of the learning assessment, the

instructor moves to wrap up the lesson. If the learning assessment is not satisfactory, the instructor again discusses the topic that is not apparent to the students.

The strengths of the proposed framework are the employment of active learning activities, create an environment of SS and SI interactions, and course conduction using synchronous teaching. The proposed framework can be designed based on the lesson duration. In our university, the typical duration of a lesson is 1 h and 50 min. However, the proposed framework can be re-structured and set the active learning activities for a class of 50 min duration. The framework structure may vary depending on the instructor and courses; however, implement the framework during RTL is crucial.

3.2. Implementation of Active Student Engagement Framework

The practical implementation of the proposed framework can ensure active student engagement. The proposed framework implementation can be more straightforward in F2F course conduction. However, it is challenging to implement the proposed framework for a course in RTL because the implementation performance depends not only on designing activities but also on the technology used to exercise the activities during course conduction. Such technologies include a learning management system, materials documentation, digital platform for delivering materials, activities implementation, digital writing devices, etc. Moreover, the technology skill competency is essential for the instructors and learners to implement the activities smoothly. Otherwise, the activities' implementation may create a distraction to the participants connected to the teaching and learning process.

The course materials are documented using PowerPoint slides and designed based on the framework described in the preceding subsection. A learning management system, Moodle, in the e-learning platform is extensively used to provide course contents, such as customized handouts, announcements related to the course, recorded sessions of synchronous and asynchronous teaching and learning, and video-recorded laboratory experiments. The Moodle is also used for a discussion forum, formative and summative assessments online, and communication with the learners. Figure 3a,b show a snapshot view of the course shell created in Moodle in the e-learning platform that includes the activities on the course site.

The lesson bridging between two lessons is designed based on the visual context instead of reviewing by oral presentation. This approach engages students from the right beginning of the lesson starts. Figure 4 shows a PowerPoint slide designed with visual content for reviewing or bridging the last session with the current session. The ConcepTest is one of the key activities that engage the students in a fun way and provide good feedback to the instructor about the learners' knowledge level. The ConcepTest can be implemented in RTL using different interactive presentation tools, such as Mentimeter, Kahoot, Slido, Prezi, Google Slides, Keynote, etc. These tools are freely available and can be learned quickly. This study uses Mentimeter frequently to assess the students' understanding of the previously discussed materials or any new materials expected to deliver in the lesson. Figure 5 shows activities and student engagement for different courses during the RTL. All these tests are conducted to quickly evaluate students' knowledge and understanding based on the previous lessons. One of the good features of the Mentimeter tool is that the results for the first few seconds can be hidden from the participants so that the nonresponsive students cannot sense the results from the other students' responses.

SQU E-LEARNING SYSTEM (ACADEMIC) E-LEARNING SERVICES SQU LIBRARIES SQU PORTAL ATTENDANCE RAZZAQL AHSHAN

ECCE4358_razzaqul_Fall20

- Participants
- Badges
- Competencies
- Grades
- Home
- Dashboard
- Calendar
- Private files
- Content bank
- My courses
 - ECCE2016_razzaqul_Summer
 - ECCE4358_razzaqul_Fall20**
 - ECCE4358_razzaqul_Fall20_f

Announcements

Quiz 1

Quiz 1 will be held on Tuesday, Oct. 20, 2020.
Time: 6:15 PM
Syllabus: Chapter 1 and Chapter 2(Up to Current Transformers)
Location: e-learning course site

Hidden from students

Midterm Exam

The midterm exam will be held on WEEK 9, November 8, Sunday.
Time: 6:15 PM
Syllabus: Handout Chapter 1 and 2 .
Location: e-learning course site.

Course outline

ECCE4358 Course outline FL20

Course materials

- Chapter 1 Energy Conversion Principle.
- Chapter 2 Special Three-phase Transformers 2.5MB

(a)

SQU E-LEARNING SYSTEM (ACADEMIC) E-LEARNING SERVICES SQU LIBRARIES SQU PORTAL ATTENDANCE RAZZAQL AHSHAN

ECCE2016_razzaqul_Summer21

- Participants
- Badges
- Competencies
- Grades
- Home
- Dashboard
- Calendar
- Private files
- Content bank
- My courses
 - ECCE2016_razzaqul_Summer**
 - ECCE4358_razzaqul_Fall20
 - ECCE4358_razzaqul_Fall20_f

Lab Report Submissions

- Guideline Sample lab report 2020 189KB
Hidden from students
- Lab 1 Report Submission
- Lab 2 Report Submission
Hidden from students
- Lab 3 Report Submission
Hidden from students
- Lab 4 Report Submission
Hidden from students

CLASSROOM FOR ONLINE (SYNCHRONOUS) TEACHING

ECCE2016_Section 10_Classroom_Dr. Razzaqul Ahshan

Video Links of Online Teaching Session (Synchronous)_Section 10_Dr. Razzaqul Ahshan

- Week 1_June 20, 2021_ Sunday_Course outline
- Week 1_June 21, 2021_ Monday_Chapter 1
- Week 1_June 22, 2021_ Tuesday_Chapter 1
- Week 1_June 23, 2021_ Wednesday_Chapter 2
- Week 2_June 27, 2021_ Sunday_Chapter 2

(b)

Figure 3. A partial view of the course site set up in the Moodle: (a) Electrical Machines course offered in Fall 2020, (b) Circuit Analysis course offered in Summer 2021.

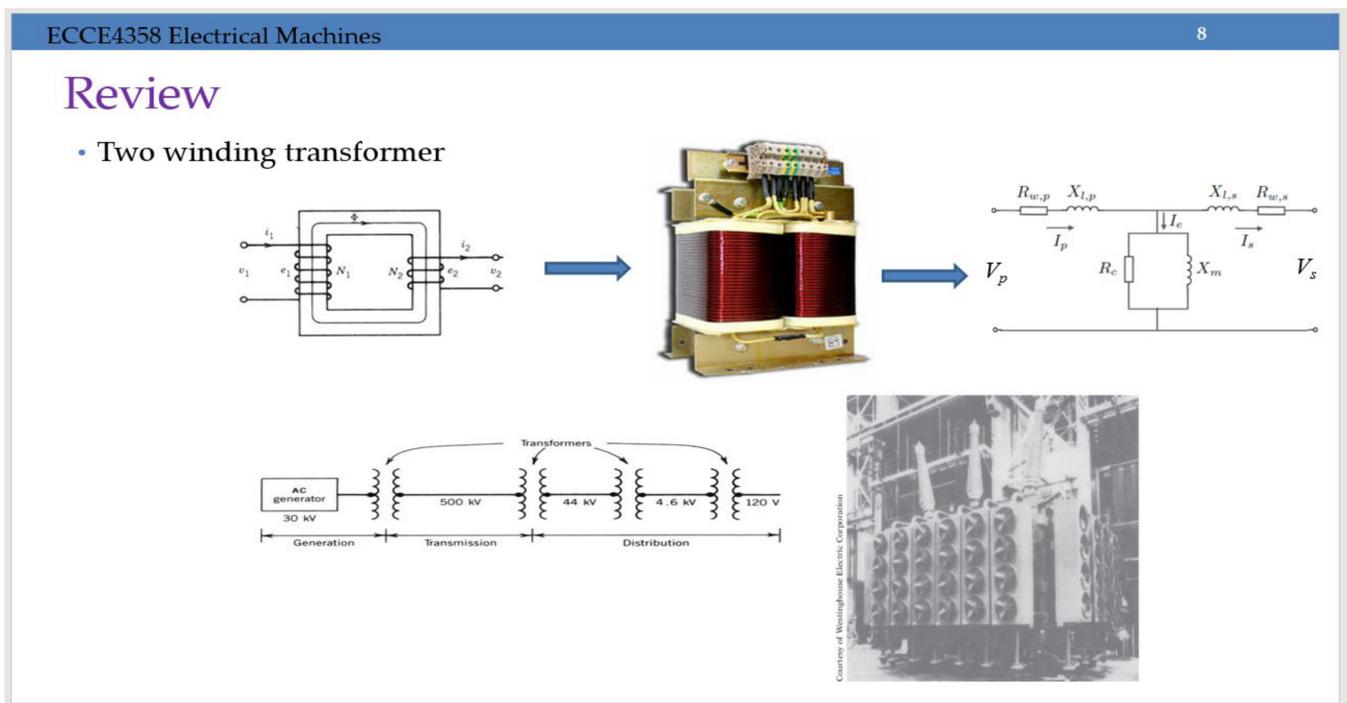


Figure 4. Sample PowerPoint slide used for bridging the lesson for the Electrical Machines course.

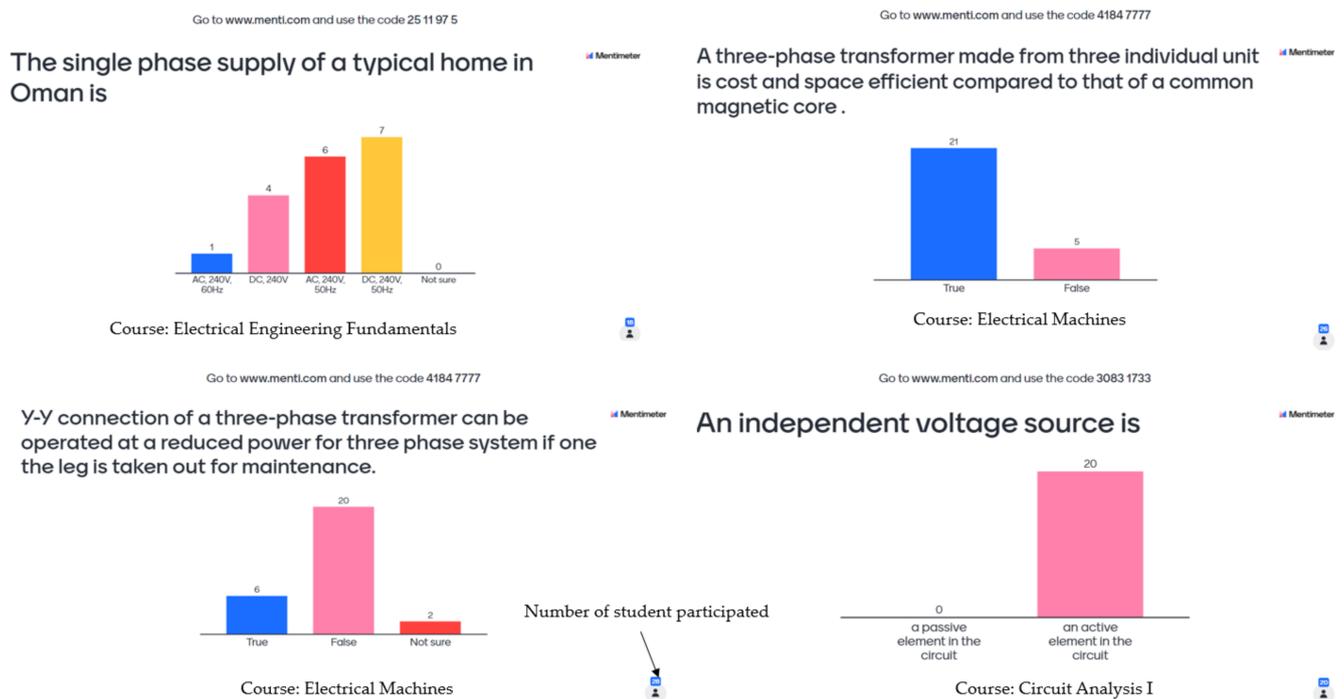


Figure 5. A sample of ConcepTest activities using Mentimeter interactive software tool for different courses.

It is essential to clearly state the learning objectives for the lesson before delivering the lesson’s materials. The learning objectives are designed based on the skills, concepts, and knowledge that the learners should gain at the end of the study. Thanks to Bloom for creating the taxonomy pyramid widely used for developing the learning objectives for a lesson or a course. Figure 6 presents an example of learning goals for one of the lessons in Electrical Machines and Electrical Engineering Fundamentals courses.

ECCE 4358 Electrical Machines	Learning Objectives
<p>Major Topic</p> <ul style="list-style-type: none"> Unbalanced Operation of 3-phase inductor machine 	<p>At the end of this chapter on AC circuits, you should be able to:</p> <ul style="list-style-type: none"> Explain AC circuits terms and terminologies. Explain the phasor concept in AC circuits. Calculate peak voltage and current, rms voltage and current, maximum voltage and current, and power for AC circuits. Explain the concept of inductive, capacitive and resistive AC circuits Explain the concept of power in AC circuits
<p>Learning Objectives</p> <p><i>At the end of the lesson on the above mentioned topic, you should be able to</i></p> <ul style="list-style-type: none"> explain unbalanced operation of the 3-phase induction machines analyses machine performance under unbalanced scenarios compare the performance of 3-phase induction machines under balanced and unbalanced operation 	

Figure 6. Sample of learning objectives for a lesson (Electrical Machines course) or a chapter (Electrical Engineering Fundamentals course).

The delivery of learning materials is exercised using synchronous teaching. Different tools, such as Google Meet, ZOOM, BigBlueButton, Webex Meetings, GoToMeeting, etc., can perform real-time online education or meeting. This study uses Google Meet (GM), which provides identical protections as Google uses to secure its users' information. It is easy to use, flexible in adjusting the schedules, quick in receiving the recorded sessions through Google email (Gmail) saved in google drive. The link to the recorded lessons is uploaded to the Moodle course site for later use, if necessary. This tool is also easy for the participant, where the learners can share their activities in class through screen sharing options. In GM, the Google Chat is another helpful option that can be used frequently for online interactions among the students and instructors. The PowerPoint slides with the necessary animation help for the effective delivery of the lesson materials using GM. Figure 7a illustrates a sample of setting up a synchronous session in GM using Google Calendar, whereas Figure 7b reveals Moodle archive of the links for the recorded synchronous teaching sessions in the course shell.

Figure 7. (a) Illustration of a class set up in GM, (b) Moodle archive of the links for recorded synchronous teaching session using GM.

Eye contact and delivery with a blackboard or whiteboard aid are essential practices in F2F classes, which is another challenging task to implement in RTL. It is because whiteboard and eye contact options are missing in RTL. Some of the features in Microsoft PowerPoint helps in highlighting the key points in the presentation and allows writing on the slides; however, it is inefficient. Therefore, a digital writing platform is essential during synchronous teaching. Some external devices, such as tablets with a pen (iPads, Galaxy Tabs, etc.) or tablet come laptop (Microsoft Surface Pro, Acer 360 laptop, etc.), are available for digital writing. These external device options are expensive; however, they are also efficient and smooth. A cheaper option of electronic devices, such as Inspiroy Dial Q620M

Huion and Wacom, is also available. This study primarily uses Microsoft Surface Pro 7 as an electronic writing tool, which does not need any physical connections between the main device (a desktop/laptop) and the writing platform. Figure 8a shows the device set up that includes the main device (a desktop) to display the lesson contents using PowerPoint and the electronic writing device (Microsoft Surface Pro 7). The instructor needs to join the meeting and present the materials from this (Microsoft Surface Pro 7) device and use the screen for writing. This study also uses Inspiroy Dial Q620M Huion Tablet as an electronic writing tool, which needs a wire connection to the main device (a desktop/laptop) and an installed driver in the main device. Figure 8b shows the device set up that includes the main device (a desktop) to display the lesson contents using PowerPoint and the electronic writing device (Inspiroy Dial Q620M Huion Tablet).

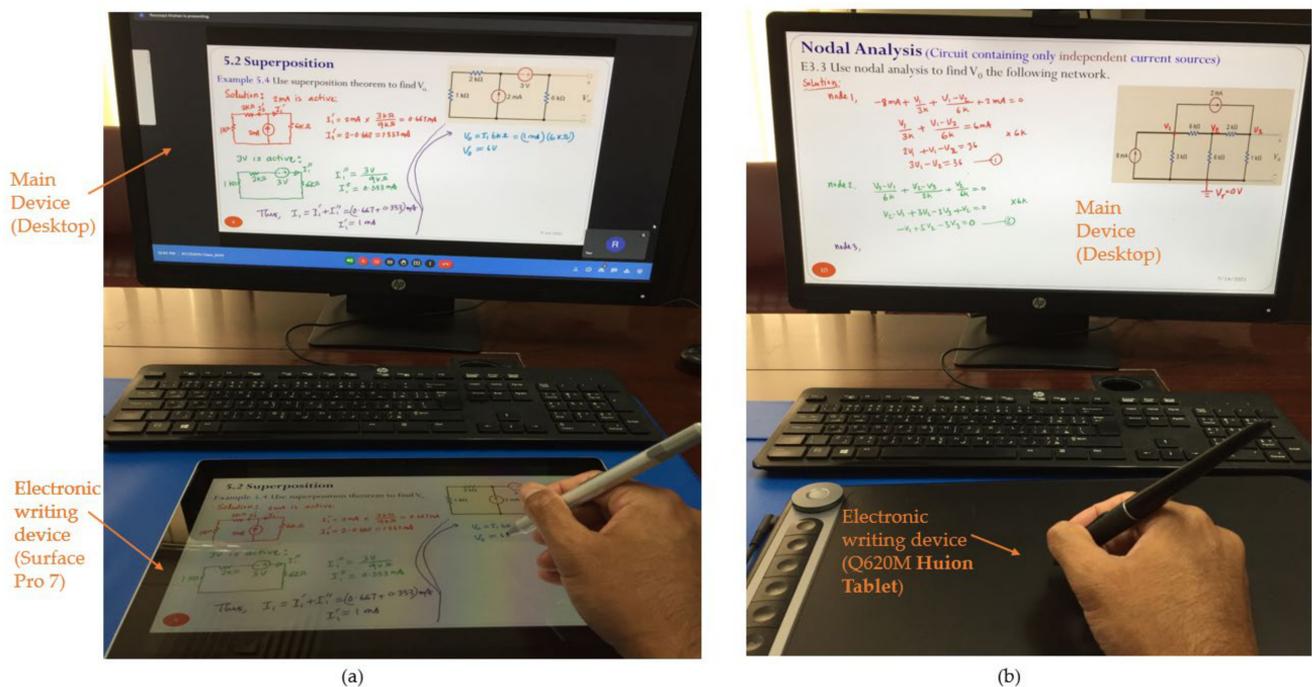


Figure 8. Illustration of two types of device set up used in RTL: (a) a combination of the main display device (a desktop) and an electronic writing device (Surface Pro 7), (b) a combination of the main display device (a desktop) and an electronic writing device (Inspiroy Dial Q620M Huion Tablet).

Think-pair-share active learning activity defines an individual activity, students work in a pair, and pair reports [1]. This activity in RTL is implemented using Jamboard (also called whiteboard) option available in the GM. The Jamboard provides real-time SI and SS interactions during synchronous teaching. The instructor requires to open and share the Jamboard with the learners during the online sessions. Using the shared Jamboard, the learners present their workings on their assigned problems. There are multiple pages in one shared link of the Jamborad, where each student or a pair of students works on a single page. The instructor can easily navigate through the different pages of the Jamboard to collaborate with each student or the team of students. The use of Jamboard allows the instructor to provide immediate feedback on the learners' tasks. Figure 9 shows the sample students' work using Jamborad. It is worth mentioning that the think-pair-share activity can also be implemented using the Google Meet Breakout Room feature.

Handwritten student work on a Jamboard showing calculations for torque T_e .

Top left calculation:

$$T_e = \frac{PZ}{2\pi a} \phi_p I_a = \frac{576 \times 123.5 \times 20 \times 10^{-3}}{2\pi} = 226.43 \text{ Nm}$$

Top right calculation:

$$T_e = \frac{PZ}{2\pi a} \phi_p I_a = \frac{576 \times 20 \times 10^{-3}}{2\pi} \times 123.5$$

Bottom left derivation:

$$T = k_a \phi_p I_a$$

$$p = a$$

$$k_a = \frac{Z}{2\pi a}$$

$$T = \frac{Z}{2\pi a} \phi_p I_a$$

$$= \frac{576}{2\pi} \times 20 \times 10^{-3} \times 123.5 = 222.89 \text{ Nm}$$

Bottom right derivation:

$$T_e = k_a \phi_p I_a = \frac{Z}{2\pi a} \phi_p I_a$$

$$= \frac{576}{2\pi} \times 20 \times 10^{-3} \times 123.5$$

$$T_e = 222.89 \text{ Nm}$$

Figure 9. Sample student work done in Jamboard during synchronous teaching.

Small group activity is another key to enhance active student engagement in the teaching and learning process. This study uses a great feature, Google Meet Breakout Room (GMBR), to implement small group activities effectively and efficiently in the GM platform. The GMBR is a freely available feature that any Gmail account user can use it. The breakout room creation is simple and easy. The GMBR allows the creation of several individual rooms for a class or course. It is up to the instructor to decide how many rooms are needed. Each room generates an independent link that can be assigned to a specific group of students. The GMBR allows the instructor to access each room and discuss with the group in a particular room. It also allows the learners to present their work to the group members and the instructor. Figure 10a represents the menu, where the courses are added for breakout rooms. This study added three different courses to practice small group activities using breakout rooms. Figure 10b presents the menu that explains the specific course and the number of breakout rooms used for a class of this course. Figure 10c shows the links for each breakout room, including the main room. It is worth mentioning that the main room is where all students interact with the instructor and their peers. However, the breakout room is for the interaction of a specific group and the instructor.

Learning assessment is a task that assesses the students' understanding and provides an active engagement. A learning assessment question that is embedded into the PowerPoint slide needs to be designed by the instructor. Depending upon the questions, a tool is required to engage students in the assessment process and receive the students' responses. This study uses Moodle course sites, Jamboard, Google Chat, and Mentimeter to perform learning assessments. Figure 11a shows a sample learning assessment question set to answer through the Moodle course shell. At the time of learning assessment, students were asked to work on the given assessment task and upload their work into the specific folder on the course site. Figure 11b presents the submission of students' work on the Moodle course site. In addition, an activity called Exit Card in F2F, that now can be defined as an Electronic Exit Card (EEC), was implemented through Google Chat. In this activity, students frequently need to write or list at least a few things they have learned in the current lesson or wish to see the discussion in the next class. Figure 11b also shows a sample of students' work of EEC using Google Chat.

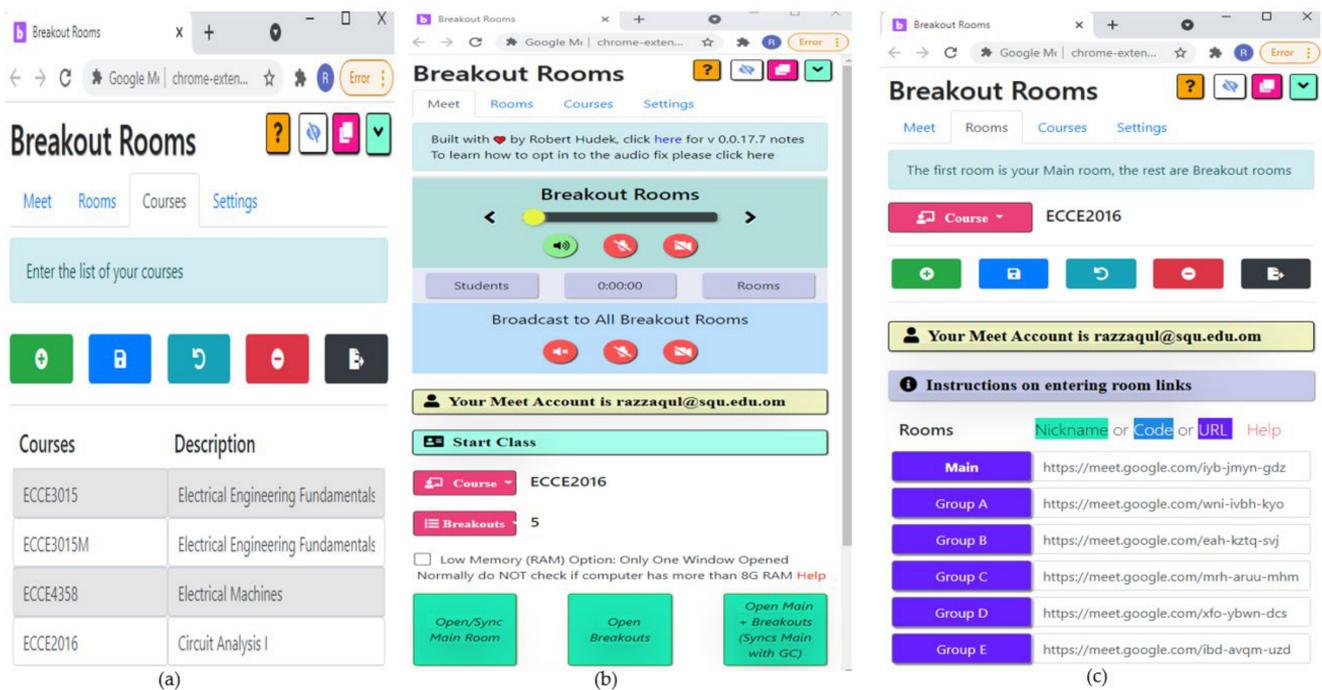


Figure 10. Google meet breakout room set up: (a) course set up menu, (b) menu that shows specific course with a number of breakout rooms, (c) the links for the breakout rooms.

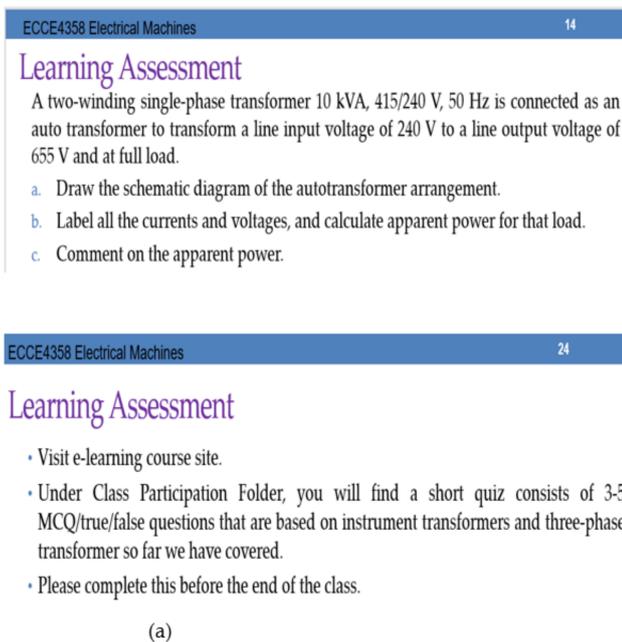


Figure 11. Student engagement through learning assessment activity: (a) design learning assessment embedded in the PowerPoint slides, (b) learning assessment submission through the submission folder in the Moodle, and a sample of Google Chat of the students upon asking to list two things that they have learned in a given lesson.

3.3. Evaluation of Active Student Engagement Framework

The instructor designed a range of questionnaires to evaluate the students' perception of the implemented framework of active student engagement using the previously mentioned tools, technologies, and activities. A survey was conducted for different courses over the last year based on these questionnaires using Google Form. These questionnaires hold the main research questions raised earlier in Section 2. The survey for various classes using

the same questionnaires allows evaluating the robustness, performance, and acceptance of the developed framework by the students of different cohorts. The questionnaires are as follows:

1. What kind of device have you used frequently to attend the class? (Choices: Laptop/Desktop/Tablet/Mobile);
2. How would you rate your internet connection (speed) during the class you have attended? (Choices: Excellent/Very good/Good/Satisfactory/Poor);
3. How would you rate (in terms of friendly) the course site (in Moodle) that the course instructor prepared? (Choices: Excellent/Very good/Good/Satisfactory/Poor);
4. The instructor frequently uses Google Chat for interactive online teaching and learning for this course. (Choices: Strongly agree/Agree/Disagree/Strongly disagree/Not applicable);
5. The instructor frequently uses Jamboard for interactive online teaching and learning for this course. (Choices: Strongly agree/Agree/Disagree/Strongly disagree/Not applicable);
6. The instructor frequently uses Mentimeter for interactive online teaching and learning for this course. (Choices: Strongly agree/Agree/Disagree/Strongly disagree/Not applicable);
7. The instructor uses the Google Meet Breakout Room for interactive online teaching and learning for this course. (Choices: Strongly agree/Agree/Disagree/Strongly disagree/Not applicable);
8. Online teaching aids, such as voice, screen, writing on the slides, or writing pad-using surface pro were effective. (Choices: Strongly agree/Agree/Disagree/Strongly disagree/Not applicable);
9. Which of the following tools provide more interactive learning, do you think? (Choices: Google Chat/Breakout Room/Jamboard/Mentimeter/A combination of them);
10. You had recorded materials for some lectures. Most of the classes were conducted through direct teaching by the instructor. Which mode of instructions do you like most? (Choices: Direct teaching (Synchronous teaching)/Recorded lecture (Asynchronous teaching));
11. Overall, which mode of instruction you found effective? (Choices: Direct teaching (Synchronous teaching)/Recorded lecture (Asynchronous teaching));
12. The instructor encouraged questions and discussions during the online sessions. (Choices: Strongly agree/Agree/Disagree/Strongly disagree/Not applicable).

4. Results and Discussion

For the purpose of evaluating the proposed active student engagement framework, an online survey was conducted based on the designed questionnaires given in Section 3.3. The survey was conducted for three different engineering courses during the Fall 2020, Spring 2021, and Summer 2021 semesters. Three engineering courses are Circuit Analysis I, Electrical Engineering Fundamentals, and Electrical Machines. Among them, Electrical Engineering Fundamentals is offered for non-electrical engineering students. In three courses, there were five sections, and a total of 153 students anonymously participated in the survey. The survey was conducted during the last week of each semester.

Figure 12 presents students' responses on using the devices in attending remote teaching and learning sessions. The majority of the students (73%) use laptops during their online class sessions, while 15% use mobile phones. The least percentage (6%) of students utilize desktops and tablets. A device plays a vital role in active participation and interaction in online classes. A device with a larger screen provides better visibility, less pressure on the eyes, and allows to work on multiple windows or menus at a time. These options become limited in the case of smaller screen devices, such as mobile phones. Since most students use large screen devices, such as laptops and desktops, this facilitates active student engagement during remote teaching and learning.

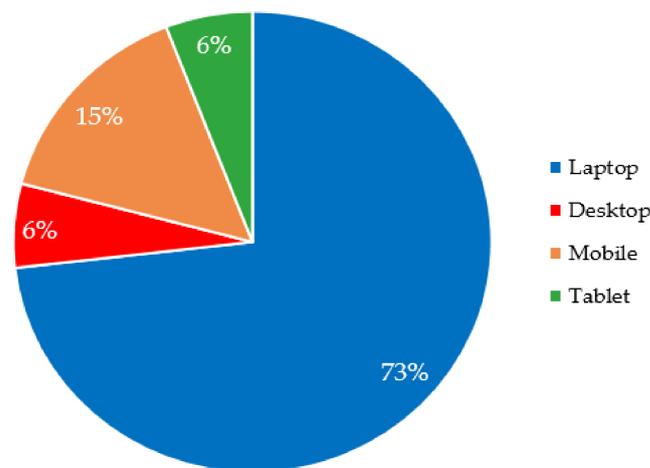


Figure 12. Devices used by the students attending remote teaching and learning classes.

In remote teaching and learning sessions, the communication infrastructure (such as internet speed) influences the reliable and effective interaction among the participants during the live sessions. Figure 13 shows students' responses to the internet speed found during the remote teaching and learning sessions. A small percentage (9%) of students have excellent internet speed, and this group of students has almost no interruption during the online sessions. About 57% of students have found that their internet speed is either very good or good, with a rare interruption. About 23% of students have a satisfactory internet connection, and this group of students has minimum interruption during their online sessions. However, about 11% of students have reported their internet connection is poor. This group of students faces more interruption, voice cracking during the interactive and online sessions, and sometimes complete disconnections. The health of this communication infrastructure can be attributed to internet bandwidth and the students' geographic locations from where they are attending the classes. It is important to note that majority of the students are satisfied with their internet speed that helps them engage during online teaching and learning actively.

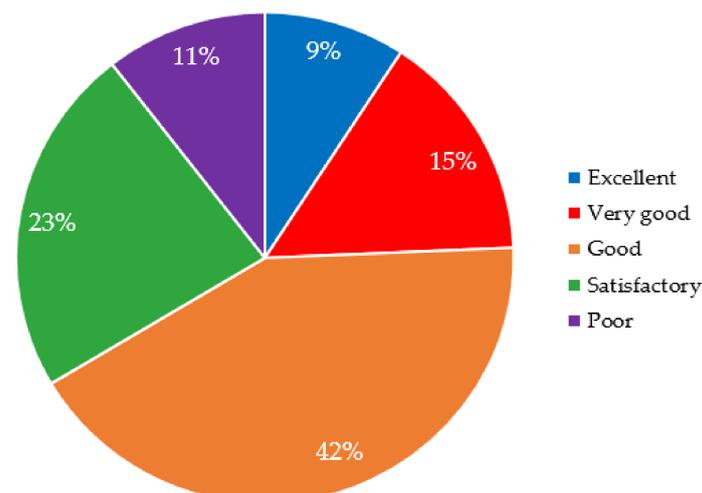


Figure 13. Health of communication infrastructure (internet speed) available at the student end for attending remote teaching and learning classes.

Figure 14 reveals the students' satisfaction with the course site designed in Moodle. The course site is an essential component for active student engagement during online teaching. The course site can provide detailed information, including course materials, class attendance links, recorded synchronous sessions, announcements, discussion forums,

assessments, etc. The course site should allow a learner to get a detailed and clear picture of the course progress. About 46% of learners indicated that the course site was excellent, whereas 36% stated a very good course site. About 17% of students express that the course site is good. These responses can be attributed to the students' activities and frequent visits to the course site, as shown in Figure 15 (this figure is directly produced from the course site). Figure 15 reveals an active student engagement both in inside and outside class sessions. Figure 15a indicates students and instructor activities log for the Electrical Machines course for the Fall 2020 semester, while 15(b) shows students and instructor activities log for the Electrical Engineering Fundamentals course for the Spring 2021 semester.

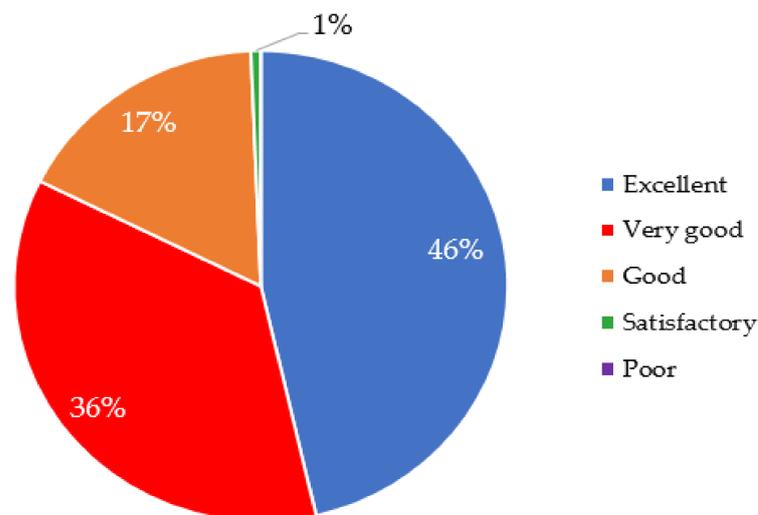


Figure 14. Student feedback on course site designed Moodle for during remote teaching and learning.

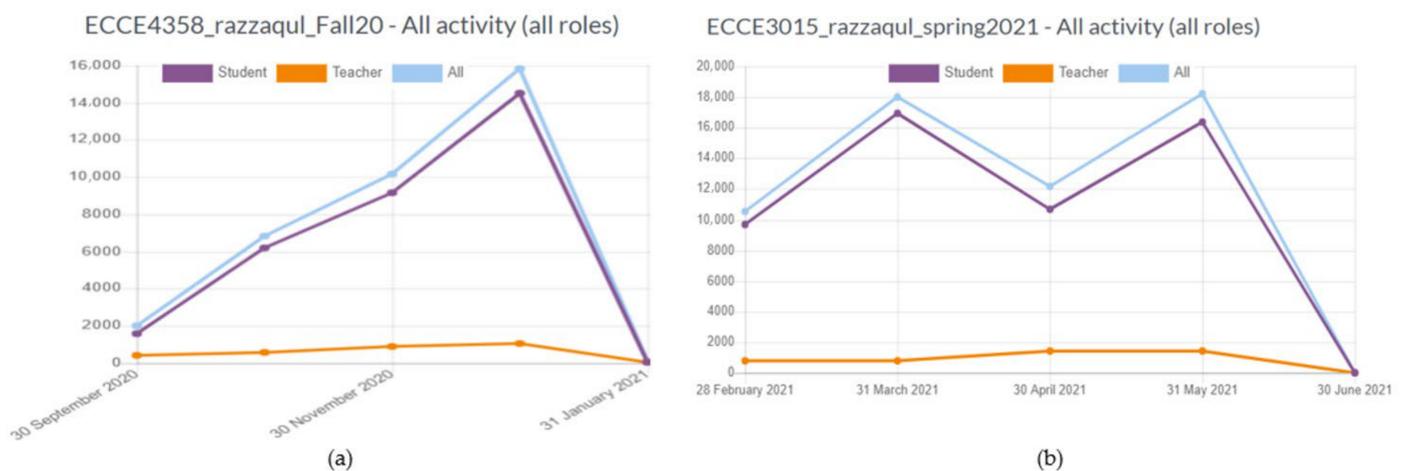


Figure 15. A sample of student activity report extracted from the Moodle course site over one semester.

Google Chat activities provide effective online SS and SI interactions during RTL by responding to the instructor or peer student queries. It allows learners to perform individual activities and respond to the instructor or peers for feedback or comments. During RTL, the instructor frequently uses this feature to create interactive teaching and learning environment. It helps to implement active learning activities, such as EEC. Figure 16 captures student responses on Google Chat used for active student engagement. It reveals that about 59% of students strongly agree on using Google Chat to create active student engagement during online sessions, while 37% agree. Only 2% of students disagree with this great tool that aids in student engagement, which can be attributed to the poor internet connection.

This condition of the internet speed can cause a learner to slack behind the regular pace of the class or disconnect the student from the online session. Overall, 96% of students have shown positive responses on this active student engagement tool and activities.

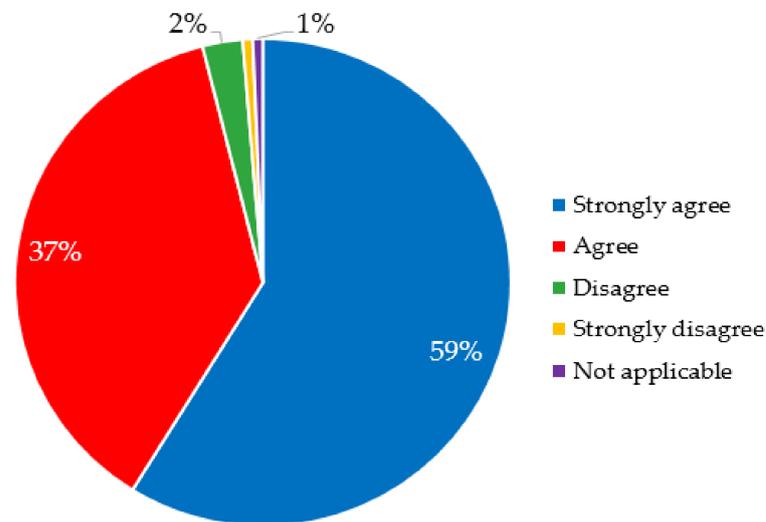


Figure 16. Students' response on active student engagement using Google Chat during remote teaching and learning.

Activities using Jamboard during online sessions provide effective SI interactions. Jamboard is an effective tool to perform active learning activities. It allows learners to exercise individual activities as assigned by the instructor. The Jamboard has multiple pages that enable students to work on the given problem and write the expected solution. The instructor navigates page by page to facilitate the students' work. This activity simulates the individual in-class work in the F2F mode of teaching. The instructor frequently uses this feature for active student engagement in RTL. Figure 17 captures students' responses on the use of Jamboard for interactive teaching and learning. It reveals that about 64% of students strongly agree on using Jamboard to create active student engagement during remote teaching and learning sessions, while 35% agree on the same. Only 1% of students disagree with this excellent tool of student engagement, and it can be attributed to the students' motivation on electronic writing skills, as students sometimes need to develop skills of writing electronically. Overall, 99% of students have shown positive responses on this active student engagement tool and activities based on this tool.

Mentimeter activities during online sessions provide real-time SI interactions and active learning activities by responding to the instructor queries. It allows presenting interactive quizzes to perform ConcepTest and learning assessment as assigned by the instructor. The Mentimeter allows immediate feedback on their work and reveals the overall status of the learners in a class. However, the mapping between the individuals and their responses remains unknown to the instructor and the participants. The instructor does not need to navigate page by page to facilitate the students' work. The instructor frequently uses this feature for active student engagement in RTL sessions. Figure 18 reveals students' responses on the use of Mentimeter for interactive teaching and learning. It indicates that about 52% of students strongly agree on using Mentimeter to create active student engagement during remote teaching and learning sessions, while 42% agree on the same. However, 4% of students disagree with this effective tool of student engagement, and it can be attributed to the folded mapping between the individuals and their responses. Overall, 94% of students have expressed a positive opinion on this active student engagement tool and activities based on this tool.

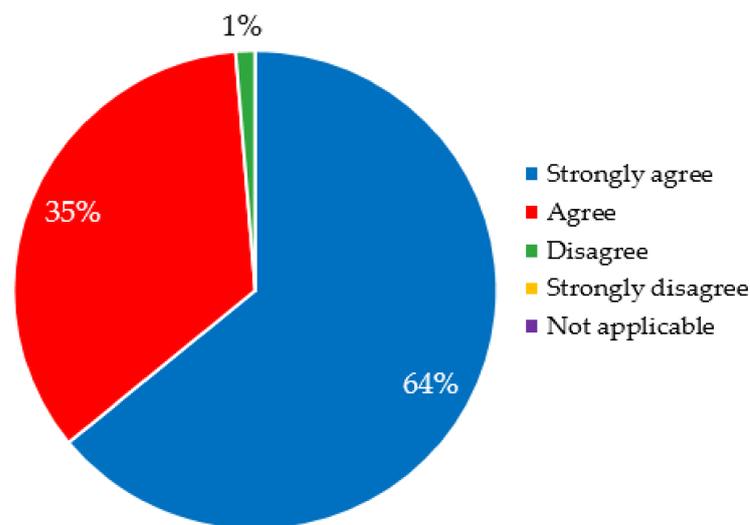


Figure 17. Students' response on active student engagement using Jamboard during remote teaching and learning.

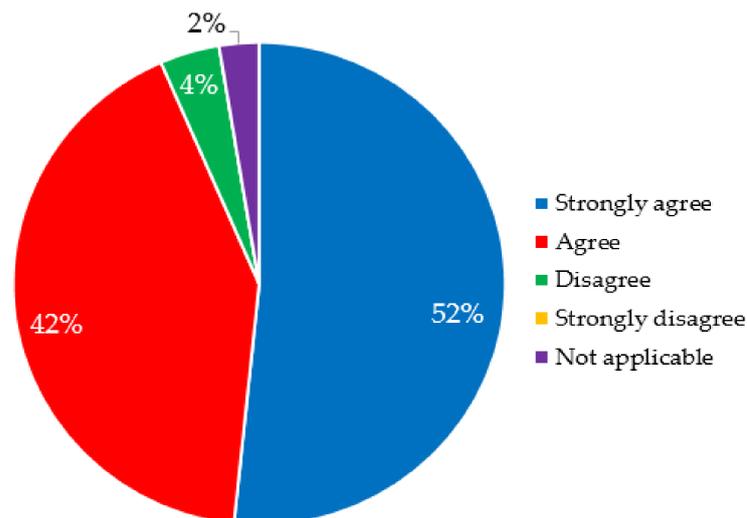


Figure 18. Students' response on active student engagement using Mentimeter during remote teaching and learning.

The Breakout room in GM allows small group activities in real-time during online sessions. This platform provides an implicit way of implementing active learning activities that enhance SS interactions, SI interactions, and social presences in RTL. Breakout room activities mimic group activities in the F2F teaching modality. The instructor frequently uses this platform, where each group was assigned one specific room and tasks to be completed during the session. It supports students in deepening their understanding and interacting with the instructor for the subject matter discussed. Figure 19 reveals students' reactions to using Breakout rooms for active student engagement through small group work activities. It indicates that about 48% of students strongly agree on using a Breakout room that creates interactive learning in a remote teaching session, while 45% agree on the same. However, 4% of students disagree with this excellent student engagement tool, and 3% indicate not applicable. It can be connected to the student with poor internet connectivity, resulting in interruptions during the group activity, as the student who faces connection interruption in a particular group, lags behind the discussion, resulting in this disagreement. Overall, 93% of students are positive and satisfied using this tool for active learning activities that enhance active student engagement.

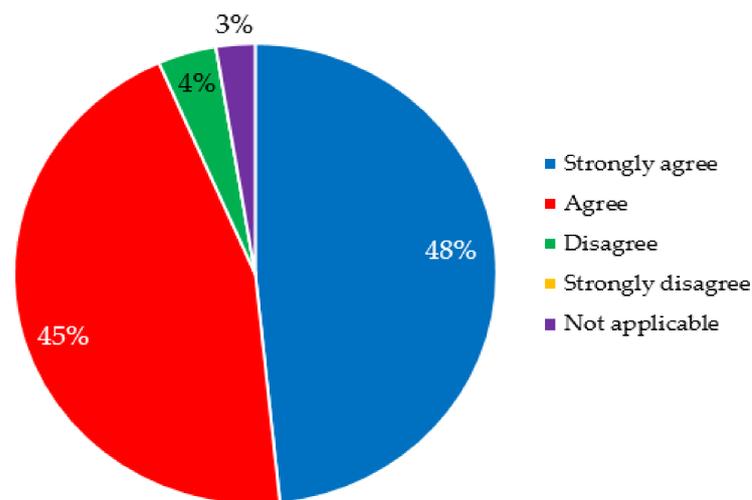


Figure 19. Students' response to active learning activities using Google Meet Breakout Room during remote teaching and learning.

Figure 20 reveals the students' view on an effective tool for implementing active learning activities to enhance active student engagement. About 43% of students have found using a combination of tools (Google Chat, Breakout room, Jamboard, Mentimeter) is more effective in implementing active student engagement. A 25% of students have observed the Google Chat, and 17% have indicated Jamboard alone is adequate for active student engagement. Further, 14% of students have seen that the Breakout room activity is more interactive for engaging students. The proposed framework is designed to require a combination of the tools to carry out the teaching and learning activities, which is also evident from the students' feedback.

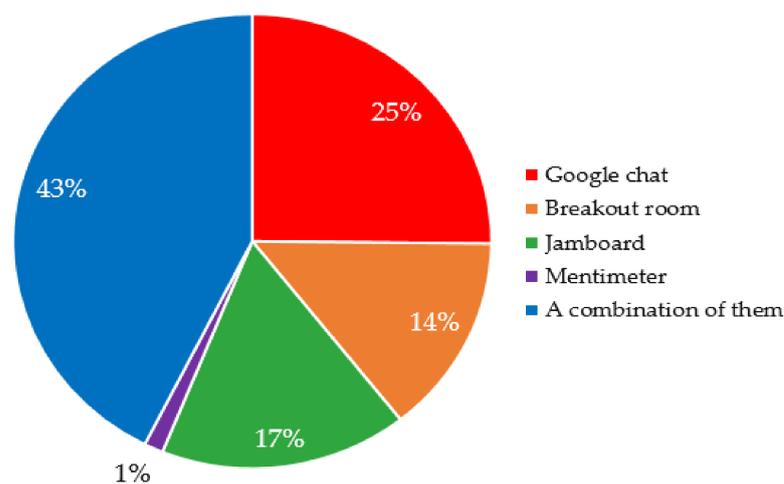


Figure 20. Student's feedback suggesting practical tools for active student engagement during remote teaching and learning.

Figure 21 reveals the students' responses on the effectiveness of using online teaching aids, such as voice, screen, writing on the slides, or writing pad-using surface pro during remote teaching and learning used by the instructor. About 47% of students strongly agree that the teaching aids and writing delivery used in the proposed framework were effective. A 50% of students agree that the teaching aids and writing delivery during the online session was compelling. Only 3% of students disagree that the online session's teaching aids and writing delivery were ineffective. It can be associated with the students who use smaller screen devices and have poor internet connections. The smaller screen in a device

does not provide better resolution to visualize the instructor's writing. The poor internet speed results in crack in the voice.

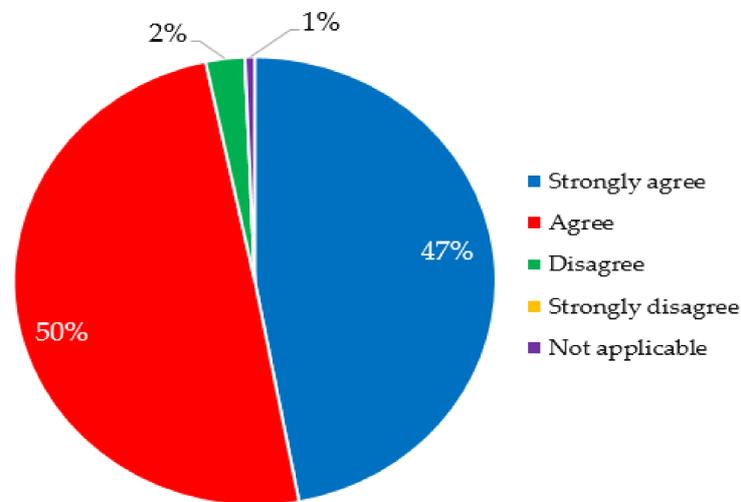


Figure 21. Students' responses on the effectiveness of using online teaching aids, such as voice, screen, writing on the slides, or writing pad-using surface pro during remote teaching and learning.

Teaching modality is an essential pillar of active student engagement during remote teaching and learning. Figure 22 presents students' feedback on the teaching modality. The instructor has conducted lessons using the synchronous teaching mode that is considered in the proposed framework. In addition, a few lectures were recorded and shared with the students during the semester, and it represents an asynchronous teaching mode. About 62% of students have found that direct or synchronous teaching is more effective, and they like this teaching modality more. This finding is consistent with the outcome presented in Ref. [1]. About 38% of students like the asynchronous or recorded lecture teaching modality. However, asynchronous teaching is not adequate for active student engagement, which was already evident by the students' responses, as shown in Figures 14 and 16–20.

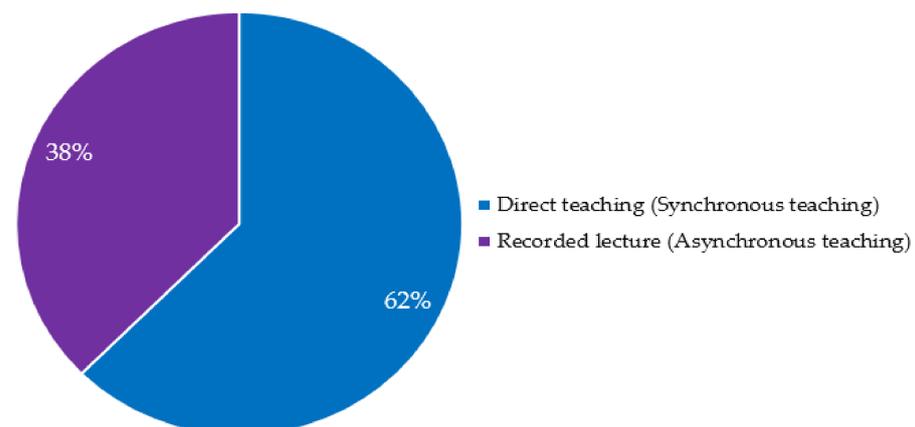


Figure 22. Students' responses on the teaching modality during remote teaching and learning.

Furthermore, the satisfaction of teaching modality is examined for the three courses considered in this study and for the other courses taken by the students involved in this survey. Figure 23 reveals students' satisfaction with teaching modalities other than the three courses, such as Circuit Analysis I, Electrical Engineering Fundamentals, and Electrical Machines, in this study. It reveals that 60% of students have found direct or synchronous teaching as an effective teaching modality for the other courses. This finding is consistent with the outcome presented in [1]. However, 40% of students like the asynchronous or

recorded lecture teaching modality. Although 40% of students like asynchronous teaching; however, asynchronous instruction is not adequate for active student engagement, which was already evident by the student's responses shown in Figures 14 and 16–20.

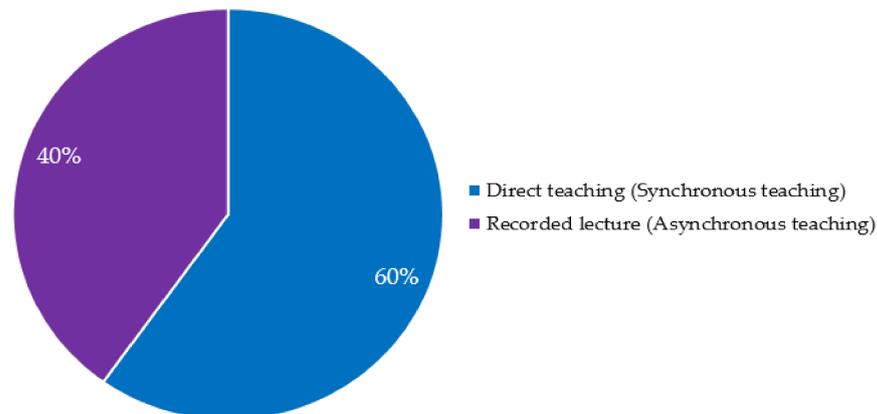


Figure 23. Students' responses on the teaching modality in general during RTL.

Figure 24 captures students' perception of the instructor's teaching strategy that encourages questions and discussions during remote teaching. Encouraging questions and discussions allow active student engagement both in RTL and F2F teaching modalities. About 65% of students strongly agree that the proposed framework's online sessions enable them to ask the instructor questions that lead to an open discussion among their peers. About 34% of students agree on the same strategy. Overall, 99% of students believe that encouraging the students for questions and discussion during online sessions provides active student engagement.

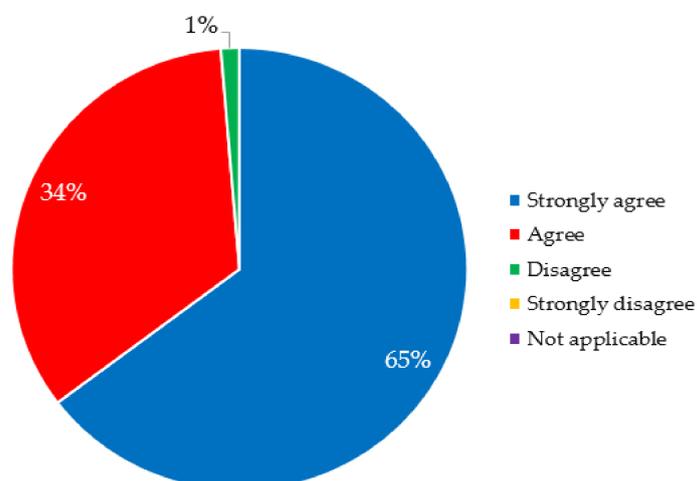


Figure 24. Students' responses on the instructor teaching strategy that encourages questions and discussions during remote teaching and learning.

5. Conclusions

This paper has presented a framework for implementing active student engagement activities in remote/online teaching during the COVID-19 pandemic. Such a framework may not be generalized for all disciplines; however, the presented framework performs well in active student engagement for engineering courses, including a fundamental course. The framework was realized by active learning activities, teaching pedagogies, utilization of technologies, and Moodle learning management system. Over the last year, the instructor practiced the framework for three semesters (Fall 2020, Spring 2021, and Summer 2021) for three different courses that totaled five sections with 153 students.

The research findings indicated that Moodle e-learning platform, Google Meet, Google Chat, Jamboard, Mentimeter, and Google Meet Breakout Room are effective tools in implementing active student engagement activities. Another key finding was that the proposed framework provides student–student, student–instructor interactions and ensures social presence during the remote/online sessions due to the active learning activities implemented by the tools, as mentioned earlier. This outcome is aligned with the research findings provided in [16,19,27,54]. Only a tiny number of students express the negative experience of the proposed framework, and it is due to unreliable communication facilities. Reliable communication infrastructure is a critical issue in RTL to ensure active student engagement for all students in a class. This study also concludes that synchronous teaching pedagogy adopted in the proposed framework was practical in active student engagement, aligning with the outcome presented in [1].

Although the proposed framework works well for the courses presented in this study, this framework can be tailored or adjusted for any engineering course. This study is an example of active student engagement implementation in remote teaching and learning during COVID-19. This insight study can benefit educators, educational policymakers, and associated stakeholders nationally and internationally for active student engagement in RTL or distance education during and post COVID-19.

One limitation of this study is that it presents only students' perspectives on the developed framework that concentrates on students' experiences and practices. The inclusion of instructors' perspectives on the developed framework will encompass both the learners' and instructors' experiences and matters. Moreover, further study is required to identify an optimal combination of the tools/technologies for active student engagement since none of the tools/technologies alone is sufficient to implement the active learning activities. Additionally, strategies for increasing social presence can be investigated for remote/online teaching and learning, considering uneven facilities of communication infrastructure and technologies/tools available with the learners.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

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