IMPACT OF E-LEARNING ON ENGINEERING EDUCATION DURING THE COVID-19 PANDEMIC: A STUDY IN THE NORTHEASTERN REGION OF INDIA

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Received: 20/12/2023 **Accepted:** 05/06/2024

ABSTRACT

The COVID-19 pandemic has put the entire world in a very challenging situation, and similar to other sectors, education has also been severely affected. The teaching-learning process during that period was carried out only online. As none of the stakeholders expected such an unprecedented situation, all the institutions had to switch to an online mode with almost zero preparation, abruptly putting the entire process in a very challenging position. This survey article aims to assess the impact of e-learning on engineering education during the pandemic in the Northeastern region of India. A carefully designed questionnaire divided into six major groups was circulated among the learners. The study addresses several research questions, including the improvement of IT skills among students, the e-learning exposure level before the pandemic, and the comparison between e-learning and face-to-face learning in terms of knowledge improvement, technical skills, and social competency. Additionally, the interest level of students in attending theoretical and lab classes in online and offline modes, students' assessment of the merits and challenges of e-learning, major obstacles faced during online learning, the overall experience of learners with e-learning during the pandemic, and students' excitement to return to college for physical learning after COVID-19 are examined. The findings highlight the need to address technological challenges, enhance online instructional design, and consider individual preferences and needs in shaping the future of engineering education. Unreliable internet connectivity and the higher cost of internet data are identified as the two major bottlenecks of e-learning in the specified region. Proper teacher training, time-efficient schedules for online classes, and selection of the most relevant e-content are some of the most important issues to be addressed for enhancing the effectiveness of e-learning.

Keywords: e-Learning, face-to-face learning, engineering students, survey, COVID-19.

INTRODUCTION

The COVID-19 pandemic has severely impacted the global education sector. The learners and educators were forced to remain stranded in their houses (Crawford, et al., 2020). The conventional methods of the teaching-learning process became almost impossible to implement. To ensure learning continuity, educational institutions

around the world have been compelled to quickly switch from physical to virtual learning environments (Gupta, Kumar, & Tekchandani, 2023). To minimize the loss of learners, the academic community considers online learning or e-learning to be the most viable alternative solution under the given circumstances. Online learning and virtual classes are now the foundation of all educational institutions worldwide.

From a user's point of view, e-learning can be accessed using a laptop, a desktop, or a smartphone with suitable communication software and a reliable internet connection (Pal, Pramanik, & Choudhury, 2019). In response to the changing requirements, teachers could transform their teaching-learning process from conventional to virtual, with minimum training or even with no training, in some cases. The students' community, too, enthusiastically embraces the changing environment of the teaching-learning process.

E-learning or electronic learning, also called technology-enhanced learning (Wheeler, 2012), can be defined as acquiring knowledge with the help of electronic resources (Tamm, 2020). It has merits as well as demerits (Bezhovski & Poorani, 2016) (Alqudah, et al., 2020). It saves time and money, as it can be scheduled around the clock and attended from anywhere (Almahasees, Mohsen, & Amin, 2021). As physical infrastructures such as classrooms, desk benches, audio-video systems, etc., are not needed, many learners can be addressed simultaneously, provided that the communication software is the same. The live classes can be recorded and used as resource material for later use if made available online. On the other hand, one of the prerequisites is access to good internet connectivity, without which learning is a disaster. The availability of a computing device is a must, and it may sometimes burden parents in very low-income groups. Security is an issue; anyone with a joining link can access the class. The assessment of learning outcomes is very challenging because students' activities cannot be monitored until they are proctored. Hands-on learning is almost impossible to implement in a virtual classroom. Social isolation is one of the side effects of e-learning.

In this paper, we developed a questionnaire encompassing the above merits and demerits to assess the e-learning experience of engineering students in India's northeastern region (NER), during the COVID-19 pandemic. The northeast part of the country has geographically difficult terrain with a sparse population density. This region is relatively less developed than the rest of the country regarding infrastructure supporting online education. Although e-learning was relatively popular in other parts of the country compared to the region of study, COVID-19 has forced the entire world, including this region, to use the completely online mode. The study aims to assess the region's learners' preparedness and motivation to embrace the e-learning mode of study. This study aimed to discover the e-learning experiences and challenges faced by young learners of engineering courses from the region during the pandemic. In particular, we sought to find answers to the following research questions through this study.

The paper's motivation is to study and assess learners' IT skills, e-learning exposure before and after the pandemic, and experience with e-learning compared to conventional forms of learning with respect to multiple parameters. More specifically, this study addresses the following research questions to assess the experience and impact of e-learning gathered by engineering students in the NER of India during the COVID-19 pandemic. Through this study, the authors also assessed the preparedness of stakeholders to address future COVID-19-like situations.

RQ1: Has there been an improvement in IT skills among students since COVID-19?

RQ2: What is the e-learning exposure level of learners before the pandemic?

RQ3: How does student experience with e-learning compare to face-to-face learning in terms of improving overall knowledge, technical skills, and social competency?

RQ4: What is the interest level of students in attending theoretical and laboratorial classes in online and offline modes?

RQ5: How do the students assess the overall merits and challenges of e-learning?

RQ6: What major obstacles did students face while pursuing online learning during the COVID-19 pandemic?

RQ7: How was the overall experience of the learners regarding e-learning gathered during the pandemic?

RQ8: Are students excited to return to college for the physical mode of learning after COVID-19, leaving the habit of online education?

With respect to the above-mentioned objectives, the major contributions of this paper are as follows:

- This study is the first to involve NER in India to assess the e-learning experience of three levels of engineering students, diploma, degree, and postgraduate engineers, during the COVID-19 pandemic.
- The survey uses a large sample size to obtain more accurate and reliable results. Of the 1425 respondents, 601, 721, and 103 were diploma, degree, and postgraduate engineering students, respectively.
- A moderate-sized questionnaire, divided into six major groups, was used. It was especially focused on assessing the learning experience, enhancement in skills, merits and challenges of e-learning, suggestions to improve, etc.
- An in-depth analysis of the survey data is presented in pictorial and tabular form for better readability.
- The study's findings are presented in the final section, along with explicit recommendations to guide policymakers and educational administrators in making e-learning more effective.

LITERATURE SURVEY

Few studies assessing the e-learning experiences of engineering students worldwide during the COVID-19 pandemic have been reported in the literature. A study to identify Indian engineering students' perceptions of currently available e-learning platforms was reported by Thakker et al. (Thakker, Parab, & Kaisare, 2020). Although Google Meet was the most preferable among all other platforms, such as Zoom, Microsoft Teams, GoToMeeting, Zoho Meeting, GoToWebinar, and Adobe Connect, all these platforms lack integration with others, for instance, conducting proctored examinations. Including new features such as annotations, split screens, live polling, and the ability to rewind would have helped make the classes more interesting for teachers and students. The survey was completed by 364 engineering students from 49 colleges in India.

Bolu et al. (Bolu, et al., 2020) investigated the problems faced by engineering students in Nigeria during the COVID-19 pandemic and suggested cost-effective and sustainable solutions for virtual learning. Power cuts and poor internet connectivity have been identified as the major bottlenecks of e-learning in Nigeria. Most respondents preferred a combined solution to the problem of power and the internet cost-effectively. 5,166 participants across the country completed the survey. A group of researchers (Alexa, et al., 2022) from the "Gheorghe Asachi" Technical University of Iasi, Romania, conducted a two-phased survey among engineering students. The first phase, in which 134 students participated, focused on learning about the online learning system offered by the university as an emergency learning mechanism. In contrast, the second phase was categorically focused on identifying the major advantages and challenges faced by the learners after they became accustomed to e-learning for almost a year. The study revealed that many students already have the necessary skills and resources to attend e-learning classes. However, the motivation level and focus gradually decreased as learning progressed in virtual form over almost a year. The know-how to handle the virtual classes was not translated into acquiring new skills and knowledge as effectively as in the conventional mode.

Asgari et al. (Asgari, et al., 2021) carried out an observational study among 627 engineering students, including 110 faculty members, at California State University, Long Beach. Logical/technical issues, teaching/learning challenges, security and privacy concerns, and insufficient hands-on training opportunities were the few factors negatively influencing online engineering education during the COVID-19 pandemic. A similar study was performed by Alkhalil et al. (Alkhalil, et al., 2021) at Al-Zaytoonah University of Jordan with the participation of 470 engineering students. The study focused on identifying the types of devices/software used, the level of engagement with teachers and student satisfaction, internet speed issues, the performance of e-learning websites, and so on. Ilangarathna et al. (Ilangarathna, et al., 2022) highlighted the e-learning experiences of Sri Lankan undergraduate engineering students during three distinct phases of the COVID-19 pandemic. The study revealed a gradual increase in students' participation in e-learning as the learners' expertise in handling e-learning resources and devices increased with time. The study involving 367 participants in connection with e-learning during the pandemic phases identified several issues. Theseincluded internet reliability, the affordability of internet bandwidth, power outages, the nonavailability of devices due to sharing among family members, missing peers, and the absence of extracurricular activities. Alkabaa (Alkabaa, 2022) conducted a study to analyze and investigate engineering students' perceptions of an online learning platform, Blackboard, at a Saudi Arabian university during the

COVID-19 pandemic. The perceptions of male and female students toward e-learning are quite different. The study recommended improving the infrastructure for e-learning and imparting necessary training to the instructors to enhance the e-learning experience of engineering students. A study to assess the impact of the online learning experience on the emotions of undergraduate engineering students in two phases was conducted by Salvador et al. (Salvador, Torre, & Pena, 2021) with a sample size of 254 at the Polytechnic University of Catalonia, Spain. The participants were not satisfied with the quality of e-learning, which degraded their academic performance. On the emotional side, the students felt discouraged, confused, bored, and worried to a greater extent. As the pandemic continued, factors other than boredom improved as people became more accustomed to handling the situation.

METHODOLOGY

This study was conducted in the NER of India. The region consists of eight states, as shown in Figure 1, with a geographical area of 2,69,179 sq. km. and a total population of 45,590,864 as per the 2011 census (Ministry of Development of North Eastern Region, Govt. of India, 2024). The region is mostly hilly and sparsely populated, with an average population density of 169.37 people/sq. Km. against the country's national average of 382 per sq. km (National Informatics Centre, Govt. of India, 2020). Regarding internet and mobile connectivity, NER (approximately 35%) lags behind the country's average (approximately 42%). The e-learners from this part of the country face more serious internet connectivity issues than those in other regions (Karmakar, 2021). The NER consists of several National Institutes of Technology (NITs), central universities, state universities and institutions, self-financed universities and institutions, and government-run and self-financed polytechnic institutions offering master's, undergraduate, and diploma-level engineering programs with durations of 2, 4, and 3 years, respectively.

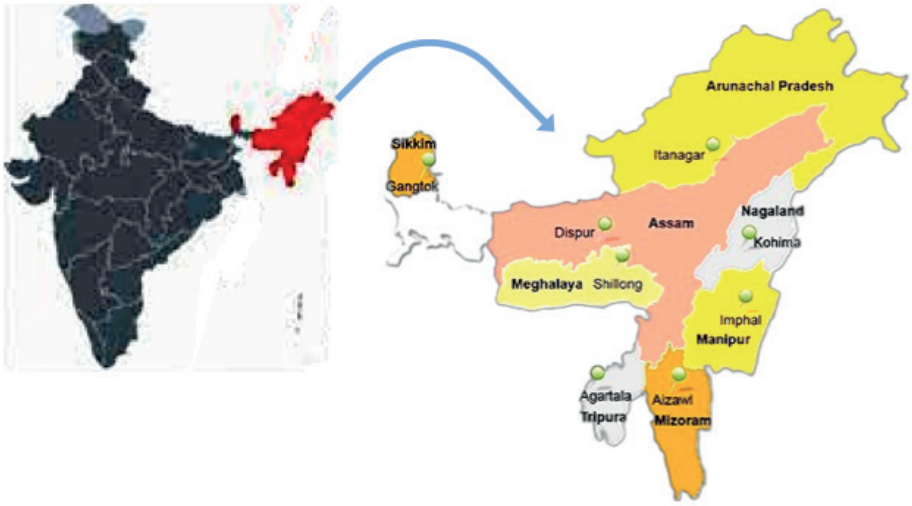

Figure 1. Location of the e-learning study region in India

Research Design

Research Method

For this study to investigate the multifaceted impact of e-learning on engineering education during the pandemic, we adopted the Mixed-Methods Research Design with a Concurrent Triangulation Design. The key reasons for this are:

- It incorporates both quantitative and qualitative data collection methods. By combining both data types, a more complete understanding of the impact of e-learning could be achieved, addressing both measurable trends and subjective experiences.

    - Quantitative data: The survey includes structured questions such as multiple-choice and Likert scale, which were analyzed using descriptive and inferential statistics. This aspect aligns with the quantitative research design.
    - Qualitative data: Open-ended questions are included to gather detailed insights and personal experiences, which were analyzed using thematic analysis. This part corresponds to the qualitative research design.
- The quantitative and qualitative data were collected concurrently rather than sequentially.
- The goal was to obtain different but complementary data on the same topic to understand better the research problem (impact of e-learning) rather than one method being dependent on the other.
- The results from both methods were analyzed separately, but results were merged to draw conclusions, as is done in a concurrent triangulation design to validate and corroborate findings, providing a comprehensive perspective on the research problem.

Population and Sampling

To finalize the selection of the survey respondents, the following factors were considered:

Target population: Engineering students in the Northeastern region of India.

Sampling technique: Stratified random sampling to ensure representation from various levels of engineering courses and also various engineering colleges across different states in the Northeastern region.

Sample size: Approximately 2000 students were approached to ensure statistical significance and diversity in responses.

Data Collection Methods

To conduct the survey and collect the responses from the respondents, the following approach was exercised:

Online questionnaire: Given the ongoing relevance of digital methods, an online questionnaire was administered using Google Forms. A deadline of two weeks was set for responses.

Questionnaire design: To find the answers to the RQs, we framed a suitable questionnaire, as mentioned in Section 1, that spanned eight sections.

- Section A: Demographic information (age, gender, year of study, institution).
- Section B: E-learning exposure and IT skills improvement (related to RQ1 and RQ2).
- Section C: Comparison of learning modes (related to RQ3).
- Section D: Interest levels in various learning modes (related to RQ4).
- Section E: Merits and challenges of e-learning (related to RQ5).
- Section F: Obstacles faced during online learning (related to RQ6).
- Section G: Overall e-learning experience (related to RQ7).
- Section H: Preference for returning to physical learning (related to RQ8).

Question types: Mix of multiple-choice questions, Likert scale questions, and open-ended questions to gather both quantitative and qualitative data.

Data Analysis Methods

The responses were stored in a spreadsheet (MS Excel) and plotted using suitable graphs for visualization, analysis, and inference.

Ethical Considerations

We ensured that the ethical factors generally involved in a survey study involving human participants were followed during this survey.

Informed consent: Participants were informed about the study's purpose and obtained consent before participation.

Confidentiality: The confidentiality of the participants' information and responses was ensured.

Voluntary participation: Participation in the survey was voluntary, and participants could withdraw at any time.

Timeline

We planned to complete the study in 12 months**.** The timeline of various stages is detailed in Figure 2.

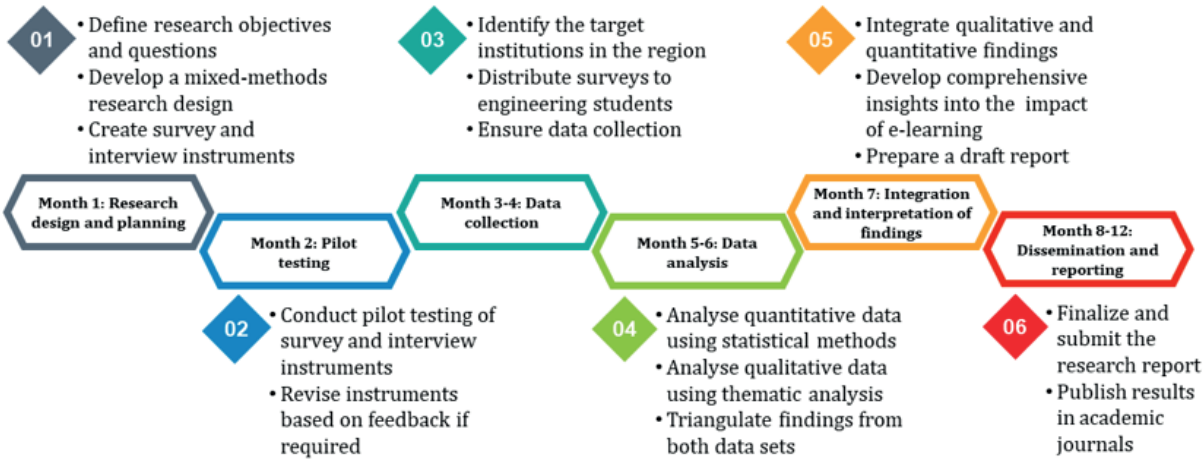

Figure 2. Graphical representation of timeline and steps involved in the study

Data Collection Tool and Distribution Mechanism

A questionnaire was designed using Google Forms and was circulated through e-mails and WhatsApp groups among the target group of students with the help of institutional authorities and faculty members in March 2022. The questionnaire included both closed- and open-ended questions based on an extensive literature survey. By this time, the students had gone through three waves of the COVID-19 pandemic, and the e-learning experience they shared can be considered the consolidated views of the learners residing in India's NER. A total of 1425 students participated in the survey, with internal breaks of 42.2%, 50.6%, and 7.2% from diplomas, degrees, and postgraduate engineers, respectively.

Survey Questionnaire

To find the answers to the research questions mentioned in Section 1, we framed a number of suitable and targeted questions for the participants. The questionnaire comprised six general questions and 17 research questions, which can be grouped as presented in Table 1. To determine the internal consistency of the survey questionnaire, Cronbach's alpha (Tavakol M, 2011) was calculated. For this purpose, feedback from 20 students was collected. The eight questions for which responses were collected at the point of scale five were used to calculate Cronbach's alpha by the following equation:

$$\propto = \frac{k}{k-1}\left(1 - \frac{V_i}{V_t}\right) \quad (1)$$

where k = the number of questions and $\frac{\sum V_i}{V_t}$ gives us information on how much of the total variance is attributed to the sum of individual variances.

After calculation, the Cronbach's alpha was found to be 0.84.

Table 1. Questionnaire description for this study

Group title	Questions	Scale
General information	Study level, branch and year of study, age, gender, institute name (optional)	Mixed type (multiple choice, textual type and numerical type)
Skill assessment	IT skills before and after COVID-19 pandemic	4-point
	E-learning experience before the pandemic	2-point
Comparison between e-learning and face-to-face learning	Effectiveness of e-learning in comparison with face-to-face learning to enhance	5-point
	Overall knowledge	
	Technical skill	
	Social competency	
	The choice between online and physical mode in attending the theoretical subjects and the practical subjects	2-point
Merits and challenges of e-learning	Advantages and disadvantages of e-learning	Multiple answers with seven choices (including 'others')
Learner's experience	Major obstacles experienced in online education during pandemic	Multiple answers with six choices (including 'others')
	Overall e-learning experience during COVID-19 pandemic	5-point
	Excitement to attend physical classes after the pandemic is over	5-point
Suggestions	Suggestions to improve the e-learning (optional)	Textual type

RESULTS ANALYSIS

This section provides an in-depth analysis of the data received from the online survey conducted among the engineering students of the NER of India studying in various branches of engineering/technology programs such as civil, mechanical, electrical, computer science, electronics, information technology, instrumentation, automobile, medical lab, textile, VLSI, thermal, data science, etc. Pictorial representations in the form of bar charts, pie charts, etc., have been presented to provide a quick understanding for the readers.

Participant Profile Analysis

Students from three levels of engineering courses participated in the survey. Diploma engineering is a 3-year course divided into six semesters, and students, after passing class 10 (16 years and above), can take admission to this course. Similarly, the degree of engineering is a 4-year course with eight semesters, and students can take admission after passing class 12 (18 years and above). After completing a degree in engineering courses (22 years and above), students can undergo 2 years of postgraduate engineering with four semesters. The survey was administered to students every year of study. A summary of the participants' profiles is presented in Figure 3. Figure 3(a) shows the level-wise average age and the standard deviation of the participants, and Figure 3(b) shows the gender-wise break-up of participants at each level of engineering courses.

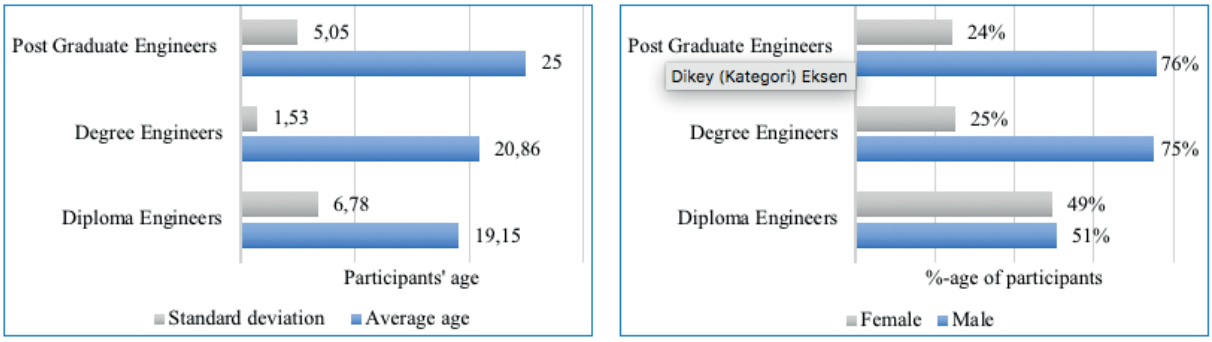

Figure 3. a) Average age and standard deviation of participants and b) Gender-wise break-up of participants

Skill Assessment

The study asked self-assessment questions on a scale ranging from excellent to poor among the participants related to enhancing their IT skills by attending online classes during the pandemic. In addition, a query related to assessing exposure to e-learning before the pandemic was also asked. The responses are pictorially presented in Figure 4 and Figure 5.

IT Skills of Participants Before and After the COVID-19

The study revealed a marginal improvement in the IT skills of the participants after they attended online classes during the pandemic period, as shown in Figure 4. Such an outcome may be expected, as the survey was conducted among engineering students, who usually have better IT skills than students studying in other disciplines.

E-learning Experience Before and After the Pandemic

The survey produced very interesting and positive results, as 44.5% of the participants in NER India had already participated in e-learning practices even before the pandemic, as shown in Figure 5. There have been efforts to popularize Swayam (https://swayam.gov.in/) courses, the Indian initiative of MOOC courses, to instill self-learning and lifelong learning. In addition, there are various opportunities for enrolling and using e-learning platforms, such as spoken tutorials, e-Yantra labs, virtual labs, Swayam Prabha, and national digital libraries, under the National Mission on Education through Information and Communication Technology (NMEICT) project of the Govt. of India have been popularized among engineering students.

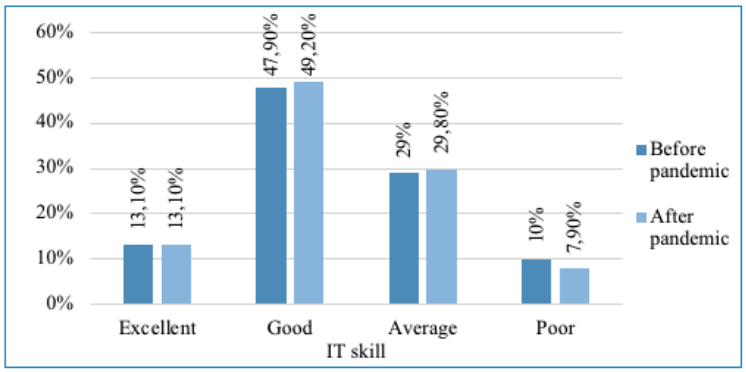

Figure 4. Levels of IT skills of participants before and after the pandemic

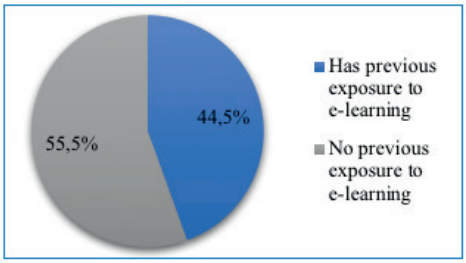

Figure 5. Number of participants with and without previous e-learning exposure

Comparison between e-Learning and Face-to-Face Learning

This study aimed to assess students' e-learning experience in comparison with face-to-face learning. Accordingly, survey questions were used to rate the effectiveness of e-learning and face-to-face learning in terms of overall knowledge, technical skills, and social competency on a five-point scale, and their responses are analyzed in the following subsections. In addition, participants' choices between online and physical modes of attending to theoretical and practical subjects were also analyzed.

Effectiveness of e-Learning and Face-to-Face Learning in Terms of Increasing Overall Knowledge, Technical Skills, and Social Competency

The participants were asked to rate the effectiveness of e-learning and face-to-face learning on a 5-point scale where 1 indicates least effective and 5 indicates highly effective. The rating statistics are shown in Figure 6. Figure 7 shows the percentage of each rating received against overall knowledge, technical skills, and social competency for e-learning and face-to-face learning, whereas Figure 8 shows the average ratings of the effectiveness of e-learning and face-to-face learning for each category.

A greater percentage of students favored face-to-face learning for all three cases, whereas a significant percentage of learners believe that a hybrid mode of learning (online and offline together) can enhance overall knowledge, technical skills, and social competency.

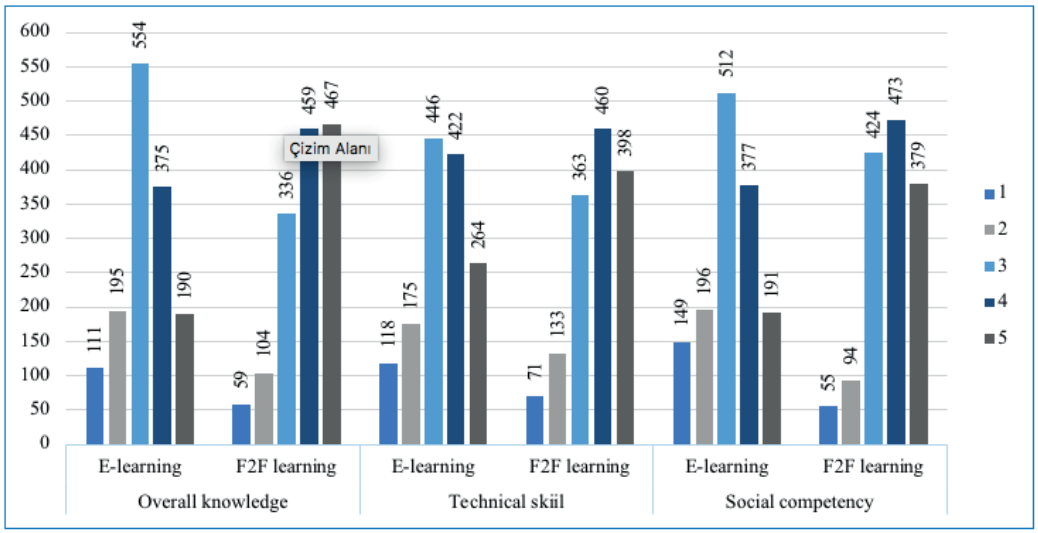

Figure 6. Participants' ratings of the effectiveness of e-learning and face-to-face learning for enhancing overall knowledge, technical skills and social competency

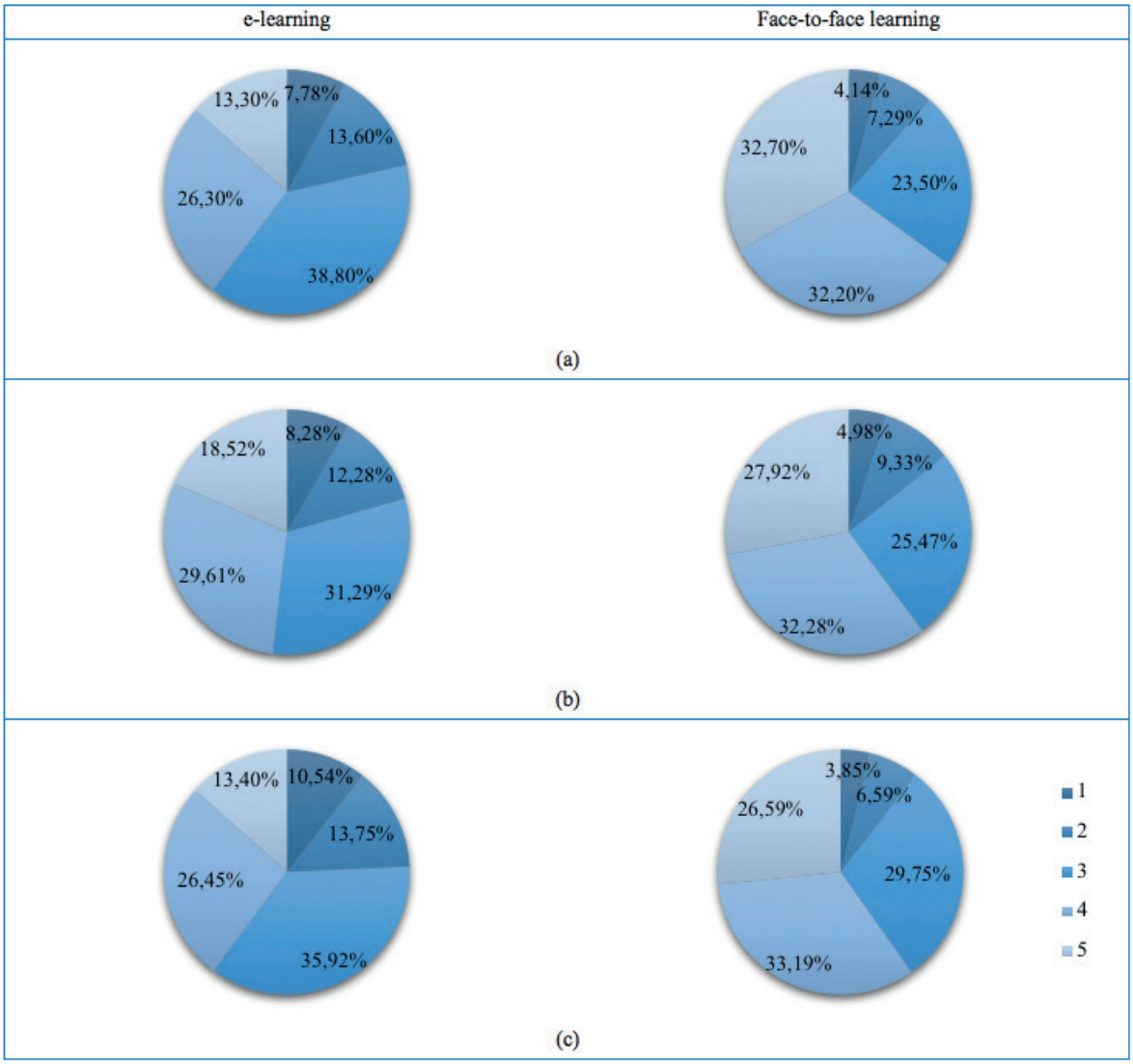

Figure 7. Participants' responses in enhancing a) overall knowledge, b) technical skills and c) social competencies through e-learning and face-to-face learning methods

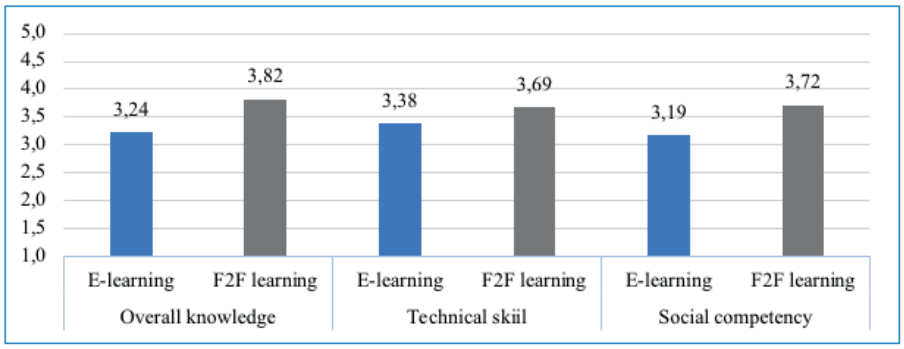

Figure 8. The weighted average of participants' endorsement of the effectiveness of e-learning and face-to-face learning on a 1 to 5 scale

Students' Interest in Theory and Laboratory Classes in Online and Offline Modes

We surveyed the students' interest in attending online or face-to-face classes for both theory and practical papers. 76.4% of students prefer the face-to-face learning mode for theory classes, whereas 90.3% prefer laboratory classes in the traditional offline mode for practical classes, as shown in Figure 9.

Merits and Challenges of e-Learning

Due to technological advancements, e-learning is gaining popularity among educators and learners. It offers many advantages but also has several disadvantages. This section analyses learners' opinions about the merits and demerits of e-learning against a few pre-established points collected from the available literature. The questionnaire provided the opportunity to agree with more than one option, and participants could also specify their points in the "others" category.

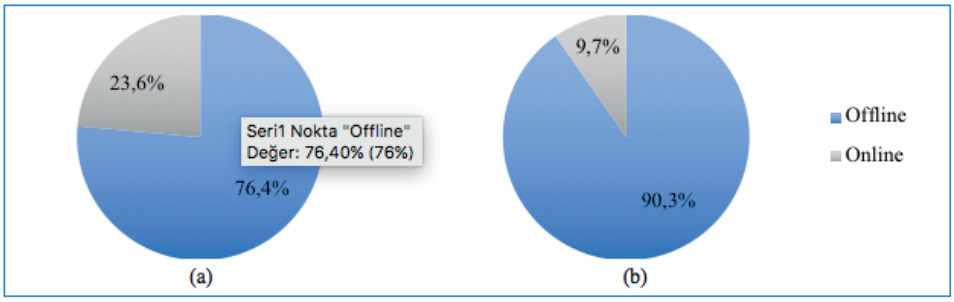

Figure 9. Participants' interest in attending (a) theoretical subjects and (b) practical subjects in the online and offline modes

Advantages of e-Learning

A list of six advantages of e-learning was offered for participant selection. The results of the students' opinions are presented in Figure 10, wherein "access to online material", "learning at your own pace", and "ability to stay at home" are the greatest advantages of e-learning. Some prominent opinions received in the "others" category are listed in Table 2.

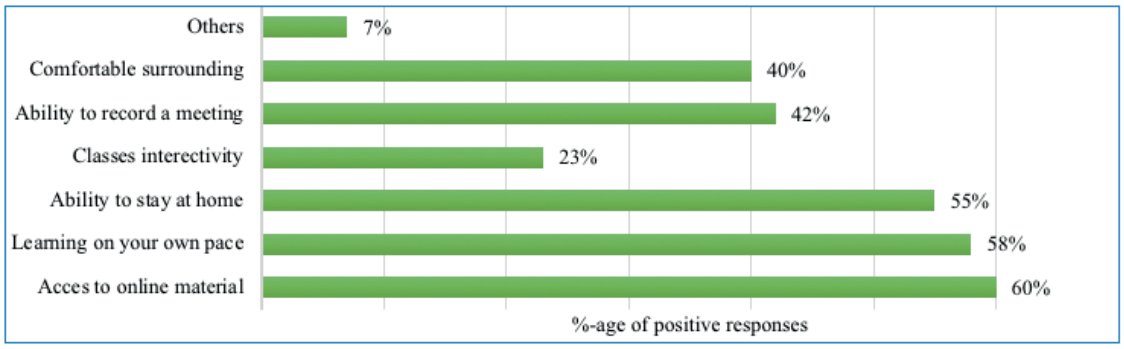

Figure 10. Participants' responses about the advantages of e-learning

Table 2. Students' opinions about the advantages and disadvantages of e-learning in the "others" category

e-learning advantages	e-learning disadvantages
More time is available to the learner for self-study and self-development	Mantle fatigue and eye-related health issues arose out of long-duration online classes
Provides safety during the COVID-19 pandemic	Lack of motivation to attend classes due to lack of an engaging environment
Scope to learn about the new teaching-learning method	Understanding classes are relatively difficult
Opportunity to access quality education without loss of time and money	Improper scheduling of classes

Disadvantages of e-Learning

As in the previous subsection, six pre-established drawbacks and the "other" category were selected by the participants in connection with the disadvantages of e-learning, as shown in Figure 11. "Technical problems" have been identified as the single major bottleneck in e-learning during the pandemic. Among others, "reduced interaction with teachers" and "lack of interaction with other learners" were considered significant drawbacks of e-learning. In the "others" category, learners identified a few issues beyond the prescribed disadvantages, as listed in Table 2.

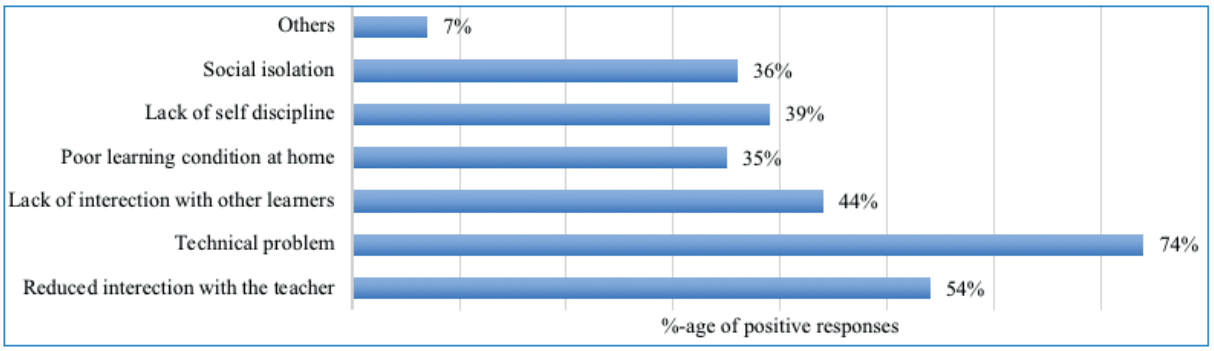

Figure 11. Participants' responses about the disadvantages of e-learning

Learners' Experience during the COVID-19

To identify the learners' experience during the COVID-19 pandemic, three different types of queries were presented to the aspiring engineers: "major obstacles experienced in online education during a pandemic," "overall e-learning experience during the COVID-19 pandemic," and "excitement to attend physical classes after the pandemic is over." The responses received are analyzed at length and presented in the following subsections.

Major Obstacles in Online Education Faced by Students during the COVID-19

This study aimed to determine the major obstacles students faced in the e-learning process during the pandemic using a multiple-answer query with five predetermined options and "others". All such options, along with participants' opinions, are depicted in Figure 12. "Unreliable internet connection" and "high cost of data" have been identified as the major hindrances to online education in this part of the world. The students highlighted issues such as the "requirement of proper training for teachers to handle online classes" and "difficulty in understanding some of the e-content" in the "others" category.

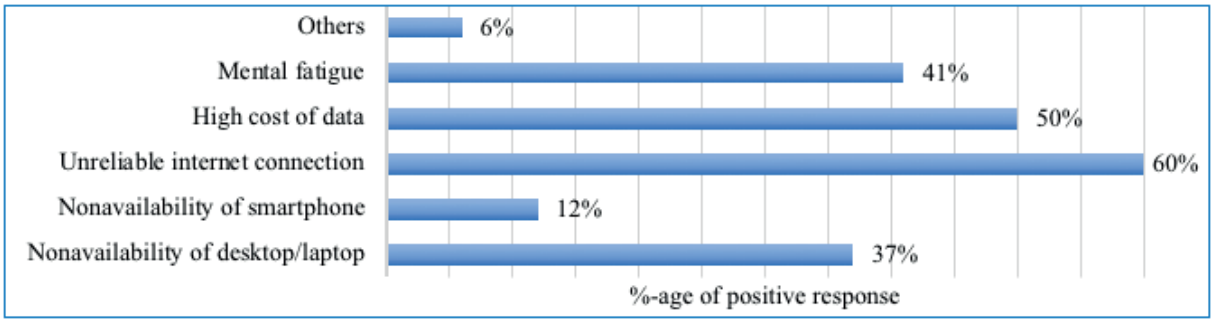

Figure 12. Participants' responses about obstacles to online education

Overall e-Learning Experience during the COVID-19 Pandemic

Another query to gather data related to the overall learning experience of budding engineers using a five-point scale (where 1 is extremely ineffective and 5 is extremely effective) has been presented in Google. Figure 13 shows that 58% of the students enjoyed the online classes, but 42% were not happy with such classes.

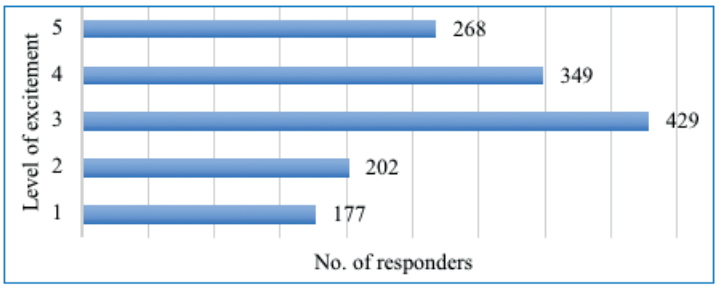

Figure 13. Participants' opinions about the overall online learning experience during the pandemic

Students' Excitement of College Reopening after the COVID-19 Pandemic

We assessed the participants' excitement to join face-to-face classes after the pandemic using a five-point scale (1 - not excited and 5 - extremely excited). The results are shown in Figure 14, which suggests that 77% of students are excited to attend classes in physical mode. On the other hand, 23% of the participants were not excited to attend their classes before the pandemic broke out. This may be due to insecurity about COVID-19 infection, dissatisfaction with the physical mode of education, or other similar reasons.

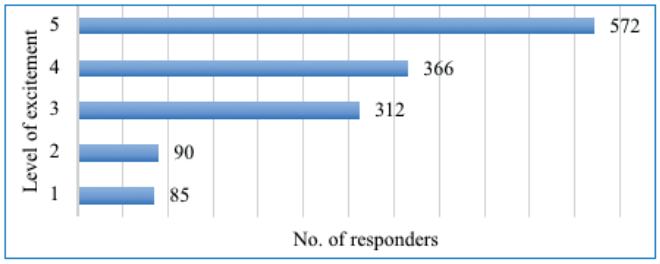

Figure 14. Summary of learners' excitement about the reopening of colleges

Suggestions

One of the important components of the survey is the ability to provide suggestions (optional) by e-learners, who can write with an open mind about their experiences and concerns. The suggestions and recommendations are classified into the following seven categories and are presented in Table 3.

Table 3. Category-wise suggestions to improve e-learning adoption and experience

Suggestion category	Summary of suggestions
Device related	• Teachers to use improved quality hardware for better clarity.
	• Financial assistance for procuring the laptops, smartphones, tablets, etc., is suggested.
Internet service and data pricing	• Consistency in internet service is very important—service to be improved. Rural areas' internet connectivity needs improvement.
	• Financial support for purchasing internet data plans for students with weaker financial status is recommended.
	• A cheap data plan for students is suggested.
Teachers' skill	• Teachers' skills in online teaching need to be improved.
	• The use of online writing boards is to enhance and improve students' learning outcomes.
	• Enhance interaction with students and support academically weaker students more.
E-content	• Proper design and judicious use of e-content are to be made for the classes.
	• Only using YouTube content is not satisfactory.
	• Sharing prerecorded videos followed by interactive sessions to clear doubts has been preferred.
	• E-content to be shared with students immediately after the class.
Class timing, duration, and class size	• A proper class schedule rather than casual timing is suggested.
	• A suitable gap between consecutive classes is desired.
	• Class duration should be shorter, and innovation in the class delivery mechanism is recommended.
	• Smaller class sizes are preferred for better interaction opportunities.
Software/app	• The software/Apps used should be bandwidth efficient.
	• Learning management system-based software/apps are preferred.
	• Other options to deliver e-resources are to be explored.
Others	• A more effective learning assessment mechanism is expected.
	• Provide an opportunity to work in a team.
	• The scope is to be provided for other social activities, too.
	• Hands-on learning is not sufficient.
	• E-learning is to be improved for mathematical subjects as well.

RECOMMENDATIONS AND CONCLUSION

The unprecedented challenge that has deeply affected the education system during the COVID-19 pandemic worldwide must be addressed and analyzed rigorously. Although the challenge of this pandemic has had some common impact worldwide, it may vary based on regional and geographical differences. This study aimed to assess, identify, and highlight the challenges faced by technical/engineering students in the NER of India in terms of e-learning during the pandemic. However, during a pandemic of this scale, learning can only be possible through a virtual mode; considering the future perspective, a blended mode of education is under consideration worldwide.

Through the study, the following key findings emerged:

- Firstly, there has been a marginal improvement in IT skills among students since the onset of COVID-19. A decent number of learners, including engineering students, had an opportunity to attend online classes before the pandemic.
- Secondly, almost half of the respondents were exposed to e-learning platforms and tools before the pandemic, but it was new exposure for the rest of the participants.
- Regarding the comparison between e-learning and face-to-face learning, the study revealed that students perceived face-to-face learning to be effective in improving overall knowledge, technical skills, and social competency. However, the specific benefits and challenges varied among students.

- The interest level of students in attending theoretical and lab classes differed between online and offline modes. Further investigation is needed to understand the factors influencing these preferences.
- The overall assessment of e-learning by students was mixed, with both merits and challenges identified. The study highlighted the need for continuous improvement in online instructional design, engagement strategies, and technical support to enhance the learning experience.
- Major obstacles faced by students during online learning included challenges related to access to technology, internet connectivity, and the lack of face-to-face interaction with peers and instructors.
- Overall, the learners' experience with e-learning during the pandemic was varied. While some students adapted well to the online mode of education, others faced difficulties adjusting to the new learning environment. The study emphasized the importance of considering individual needs and providing adequate support to ensure a positive learning experience.
- Lastly, the survey indicated that students had mixed feelings about returning to physical modes of learning after the pandemic. While some expressed excitement about the prospect of resuming face-to-face education, others had become accustomed to online learning and may not readily abandon the habit.

This study identified many areas to be improved, mostly in the online education system, along with a few issues in the offline education systems and in the geographical domain of the survey. This has shown that the online education system promulgated during the last pandemic could not impart enough technical skills to the students. The issue of reliable internet connectivity and the high cost of data are the greatest barriers to the online mode of education in this part of India. Efforts are to be made to provide reliable internet connectivity, low-cost internet data packages, and financial support for the purchase of laptops, tablets, smartphones, etc., at least for students belonging to economically backward classes, if not for all. Special attention is desired for the learners from rural areas, who find it very difficult to attend virtual classes due to poor internet coverage. All stakeholders should take the virtual learning mode more seriously, considering any future pandemic such as COVID-19. Educators/teachers should also be trained to make online teaching more effective. Learners have emphasized the need for carefully designed and effective e-content to make virtual classes more effective. The institution's management must develop an appropriate plan to handle the situation more effectively. The integration of an online platform with a learning management system is expected to enhance the performance of the e-learning system. Additionally, online platforms should be designed especially for effective practical classes. A common approach among educators/teachers would minimize the uncertainty and confusion among the students. A well-designed scientific approach to online education is required to help students reduce mental fatigue from long-duration online classes and address students' psychological issues. Although e-learning classes can be scheduled clockwise, this study recommends adopting a well-defined schedule to motivate learners. Efforts are also to be made to make the classes more engaging by providing group work or otherwise to break the monotony. On the other hand, this study also suggested that e-learning is already a popular choice among participants because learning can occur in a comfortable home environment and provides access to online material, and the learning pace may vary as session recordings are feasible. Learning during a pandemic by maintaining social distance has been identified as one of the most important advantages of e-learning.

Although, as per the study, participants showed more interest in face-to-face learning than in online learning, a few concerns are also raised by the study, indicating that some improvements are required in the conventional teaching-learning process. Our approach to data analysis has shown an agreement of 41%, 36.2%, and 42.2% in increasing overall knowledge, technical skills, and social competencies, respectively, in favour of the effectiveness of the conventional face-to-face learning process, which does not give a clear mandate toward its acceptability. This suggests that improvement is also required in face-to-face learning, which would be more engaging and could provide experiential learning, at least for engineering education in the focused region.

This study also indicates that face-to-face learning and the virtual mode of education complement each other rather than being exclusive in imparting quality technical education. This aligns with the recommendations made by other researchers in the literature.

Acknowledgements: The authors extend their heartfelt appreciation to all the students who generously dedicated their time to participate in the survey. We also express our sincere gratitude to the institute administrations and faculty members for their invaluable support and cooperation in facilitating and encouraging student participation, which greatly contributed to the success of this study.

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