Bridging the Gap: A Case Study on Implementing and Evaluating a Virtual CAD Modelling Lab for Enhanced Accessibility and Learning

Sachin B. Khot[1], Rohit Magdum[2], Prashant Jadhav[2], Ramchandra Desavale[2], Shailesh Shirguppikar[1]

1Department of Mechatronics Engineering, KES Rajarambapu Institute of Technology, Rajaramnagar, Sangli, Shivaji University Kolhapur, 415414, Maharashtra, India.
2Department of Mechanical Engineering, KES Rajarambapu Institute of Technology, Rajaramnagar, Sangli, Shivaji University
Kolhapur, 415414, Maharashtra, India.
[1]sachin.khot@ritindia.edu
[2]rohit.magdum@ritindia.edu
[2]prashant.jadhav@ritindia.edu
[2]ramchandra.desavale@ritindia.edu
[1]shailesh.shirguppikar@ritindia.edu

Abstract— **The rapid advancement of Computer-Aided Design (CAD) technology has become integral to engineering education, offering students crucial tools for visualising and simulating complex designs. However, traditional CAD laboratory setups face significant challenges, including limited accessibility, high costs, and spatial constraints, exacerbated by the COVID-19 pandemic. This study addresses these challenges by exploring the implementation of a Virtual CAD Laboratory as an alternative solution. The Virtual Lab, utilising open-source software FreeCAD, aims to provide a flexible, cost-effective, and accessible learning environment that overcomes the limitations of physical lab setups. Through systematic evaluation, including student engagement and learning outcomes, the study assesses the effectiveness of the virtual lab in maintaining educational continuity and enhancing practical skills. The findings indicate that the virtual lab has successfully ensured learning continuity, improved student engagement through 100% assignment submissions, and provided a scalable model for remote education. This research highlights the potential of virtual labs to address educational disruptions. It offers insights into best practices for their development and implementation, emphasising the need for ongoing refinement to meet evolving educational needs.**

Keywords— **Virtual Laboratory; CAD Modelling; Student Engagement; Best Practices**

ICTIEE Track- **Technology Enhanced Learning**

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I. INTRODUCTION

Computer-aided design (CAD) has revolutionized the field of engineering, making it an indispensable tool in modern engineering education. CAD refers to the use of computer systems to create, modify, analyse, and optimise designs. It encompasses a range of software applications that aid in designing everything from simple mechanical components to complex architectural structures. Its significance in engineering education cannot be overstated, as it bridges the gap between theoretical concepts and practical application (Khot et al. 2023). Firstly, CAD software allows students to visualise their designs in 2D or 3D formats, providing a more intuitive understanding of complex structures and mechanisms. This visual representation helps comprehend spatial relationships and dimensions that are often challenging to grasp through traditional drawing methods (Khot et al. 2020). With CAD, students can easily manipulate and view their designs from multiple angles, enhancing their ability to identify potential issues and refine their work.

Moreover, CAD tools offer powerful simulation capabilities. Engineering students can test their designs under various conditions using simulations to predict performance, stress, and other critical factors. This ability to perform virtual testing before physical prototyping saves time and resources and fosters a deeper understanding of engineering mechanics and materials science principles. CAD also facilitates collaboration and communication. Many CAD programs allow for real-time sharing and modification of designs among multiple users. This collaborative feature mirrors industry practices, preparing students for team-oriented environments where clear communication and collective problem-solving are crucial. Incorporating CAD into engineering curricula equips students with essential skills valued highly in the job market. Proficiency in CAD software is often a prerequisite for many engineering roles, and hands-on experience with these tools can significantly enhance a graduate's employability. Furthermore, familiarity with CAD prepares students to handle the modern engineering challenges and innovations they will encounter in their careers. Overall, CAD is vital in engineering education, enhancing design skills, promoting efficient problem-solving, and preparing students for industry demands. As technology advances, integrating CAD into engineering programs ensures that students are well-equipped to contribute effectively to their fields and adapt to future technological developments.

The traditional setup of CAD laboratories presents significant challenges that hinder effective teaching and learning in engineering education Khot et al. (2020). Accessibility remains a primary concern, as students often lack the necessary hardware, such as laptops or PCs, to run complex CAD software. The high cost of licensed software is a significant barrier, often making it unaffordable for many students. Additionally, limited physical space restricts the number of students who can engage in hands-on lab activities at the same time, resulting in inadequate practical experience. During the COVID-19 pandemic, these challenges were exacerbated, as face-to-face classes were suspended, leaving students without adequate means to engage with CAD tools. The reliance on traditional laboratory settings became untenable, highlighting the urgent need for innovative solutions that allow students to continue their education remotely. This situation has necessitated the development of a Virtual Laboratory for the CAD Modeling Lab course, enabling students to access learning resources and conduct experiments from their homes, thereby overcoming the limitations imposed by physical spaces, hardware availability, and software costs. In conclusion, the traditional CAD lab setups face significant hurdles related to accessibility, cost, and spatial constraints, which have been further intensified by the pandemic, underscoring the need for an effective virtual solution to ensure continuity in engineering education.

Virtual labs emerge as a potent solution to the challenges faced by traditional CAD lab setups, particularly in the context of the COVID-19 pandemic. These innovative platforms offer unparalleled flexibility, allowing students to engage with complex software and conduct experiments remotely from their homes. This accessibility is crucial, especially for students who may lack the necessary hardware or reliable internet connectivity to participate in conventional lab settings. Cost-effectiveness is another significant advantage of virtual labs. Traditional CAD software often requires expensive licenses, which can be prohibitive for many students. In contrast, virtual labs can utilize open-source software, making them more affordable and accessible. This democratizes learning, ensuring that all students can gain practical experience without incurring substantial costs (Kavade et al. 2017). Moreover, virtual labs help overcome physical space limitations inherent in traditional setups. By providing a virtual environment, they can accommodate more students simultaneously, enhancing collaborative learning experiences. This approach fosters greater engagement and enables iterative learning, allowing students to experiment, fail, and try again without the limitations of a physical lab. Thus, virtual labs represent a transformative solution, addressing the pressing needs of modern engineering education while ensuring continuity in learning amidst challenging circumstances.

This research aims to analyze the implementation and evaluate the effectiveness of a virtual CAD modeling lab as a response to the challenges faced in traditional lab settings during the COVID-19 pandemic. Given the restrictions imposed by physical spaces, the high costs of software licenses, and the lack of accessibility to necessary hardware, the study aims to explore how a virtual laboratory can bridge these gaps in engineering education. By utilizing open-source software, specifically FreeCAD, the research seeks to determine whether a virtual lab can provide a flexible and cost-effective alternative for students. The study will assess student engagement, learning outcomes, and the overall effectiveness of the virtual lab in delivering practical knowledge that is typically acquired through in-person lab experiences.

Through a systematic evaluation of the virtual lab's implementation, the research aims to identify best practices and areas for improvement. It ultimately contributes to the development of a robust educational model that can sustain student learning beyond conventional methods. This investigation is crucial in ensuring that engineering education remains resilient and adaptive in the face of unprecedented challenges.

The research questions answered in this case study are as mentioned further.

1. How was the virtual CAD modeling lab implemented in the case study?
2. What were the key features and components of the virtual lab setup?
3. What were the perceived advantages and disadvantages of the virtual lab compared to a traditional lab setting?
4. How did the virtual lab impact student learning and engagement in CAD modeling?

II. LITERATURE REVIEW

Virtual laboratories have emerged as a promising alternative and supplement to traditional, hands-on laboratories in engineering education. Driven by advancements in computing power, software development, and pedagogical approaches, VLs offer a simulated environment where students can engage with complex engineering concepts and processes without the constraints of physical resources or safety concerns. This section provides an overview of the existing literature on the use and effectiveness of VLs in engineering education, highlighting their benefits, challenges, and areas of ongoing research.

According to Cavanaugh et al (2008) 's analysis of the research, extroverted students analysis of the research, extroverted students may lack face-to-face connection with classmates in an online environment, while students who do not have strong verbal/reading skills may be at a disadvantage in a text-heavy online environment. According to Li and Beverly's (2008); Li (2008) review of the research, the online learning environment may not be ideal for students who struggle to stay motivated or lack self-discipline, students who are less independent or dislike working independently, students who require more hands-on assistance, students who lack basic computer skills or are uncomfortable with technology, and students who lack advanced communication, time management, and organizational skills. Concerning challenges in communication, Li and Beverly (2008) observed that there is a significantly greater potential for misinterpretation in the online environment, particularly in the effect of e-mail correspondence (e.g., students can sometimes come across as too informal and even rude, and instructors can sometimes come across as overly harsh or critical). Dykman and Davis (2008) observed that there are fewer opportunities for informal contact between students and teachers in an online classroom. These informal contacts serve to reinforce expectations and explain misunderstandings. Furthermore, when communication breaks down in an online learning setting, the situation can occasionally develop without either party realizing it until it is too late.

A. *Benefits of Virtual Labs*

Numerous studies have documented the potential benefits of VLs in enhancing engineering education:

- Increased Accessibility and Flexibility: VLs transcend geographical barriers and time constraints, providing students with 24/7 access to learning resources and enabling self-paced learning (Attarbashi et al. 2021). This is particularly beneficial for distance learners, students with disabilities, or institutions with limited lab facilities.
- Cost-Effectiveness: VLs can reduce the need for expensive equipment, maintenance, and consumables, making engineering education more affordable and accessible (Al- Gindy et al. 2020).
- Enhanced Visualization and Experimentation: VLs can offer interactive simulations, 3D visualizations, and the ability to manipulate variables and observe their effects in real time, fostering a deeper understanding of complex engineering concepts (Scalise et al., 2011)
- Safe Learning Environment: VLs provide a risk-free environment for students to experiment with potentially dangerous equipment or processes, minimizing safety concerns and allowing for exploration without fear of failure (Al-Gindy et al., 2020).
- Personalized Learning Experiences: VLs can be tailored to individual student needs and learning styles, offering adaptive feedback, personalized learning paths, and opportunities for self-assessment (Dhandabani & Sukumaran, 2014).

B. *Challenges and Limitations*

- Despite their potential, VLs also present certain challenges and limitations:
- Lack of "Real-World" Experience: Some argue that VLs cannot fully replicate the hands-on experience of working with physical equipment, potentially limiting the development of practical skills and problem-solving abilities (Attarbashi et al. 2021; Al-Gindy et al. 2020).
- Design and Development Costs: Creating high-quality VLs requires significant investment in software, hardware, and instructional design expertise, which can be a barrier for some institutions (Al-Gindy et al. 2020).
- Technical Issues and Accessibility: Technical glitches, software compatibility issues, and limited internet access can hinder the effectiveness of VLs and create barriers for some students.
- Need for Effective Pedagogical Integration: Simply providing access to VLs does not guarantee learning. Effective integration into the curriculum, clear learning objectives, and appropriate instructional support are crucial for maximizing their impact (Attarbashi et al. 2021; Scalise et al. 2011).

The field of VLs in engineering education is constantly evolving. Current research focuses on:

- Developing more realistic and immersive simulations: Incorporating virtual reality and augmented reality technologies to enhance the realism and interactivity of VLs. Investigating the impact of VLs on student learning outcomes: Conduct rigorous studies to compare the effectiveness of VLs to traditional labs in terms of knowledge acquisition, skill development, and problem-solving abilities. Exploring best practices for designing and implementing effective VLs: Developing guidelines and frameworks for creating engaging and pedagogically sound VL experiences.
- Addressing equity and accessibility issues: Ensuring that VLs are accessible to all students, regardless of their background, learning style, or physical abilities. VLs hold immense potential to transform engineering education by providing accessible, engaging, and cost-effective learning experiences. While challenges remain in replicating the full breadth of hands-on learning and ensuring equitable access, ongoing

research and technological advancements continue to push the boundaries of what is possible with VLs. As we move forward, it is crucial to adopt a critical yet optimistic approach, leveraging the strengths of VLs while addressing their limitations to create a more inclusive and effective learning environment for all engineering students.

C. CAD Modelling and Online Learning:

Computer-Aided Design has become an indispensable tool in various engineering disciplines, making its mastery crucial for aspiring engineers. The rise of online and blended learning environments has significantly impacted how CAD modelling is taught and learned. This section delves into the research on teaching and learning CAD modelling within these evolving educational landscapes.

Research suggests several pedagogical strategies to enhance online CAD learning:

- Microlearning and Chunking: Breaking down complex CAD concepts into smaller, manageable modules with clear learning objectives can improve knowledge retention and application (Dhandabani & Sukumaran, 2014).
- Interactive Learning Activities: Incorporating simulations, virtual labs, gamified exercises, and collaborative projects can provide engaging and immersive learning experiences (Scalise et al. 2011; Liu et al. 2021).
- Multimedia-Rich Content: Utilizing video tutorials, screencasts, animations, and 3D models can cater to diverse learning styles and enhance understanding (Liu et al., 2021).
- Timely and Personalized Feedback: Providing regular, constructive feedback on student work, and addressing individual learning needs, is crucial for improvement. Fostering Online Communities: Creating online forums, discussion boards, and peer-review opportunities can combat isolation and promote collaborative learning (Liu et al., 2021).

D. Emerging Trends and Technologies

The field of online CAD education is constantly evolving, with emerging trends and technologies shaping its future:

- Cloud-Based CAD Software: Cloud-based platforms offer accessibility, collaboration features, and automatic updates, eliminating software compatibility issues
- Virtual and Augmented Reality (VR/AR): Integrating VR/AR technologies can create immersive and interactive learning experiences, enhancing spatial visualization and design skills
- Artificial Intelligence: AI-powered tools can provide personalized feedback, adaptive learning paths, and intelligent tutoring systems, catering to individual learning needs.

Teaching and learning CAD modeling in online and blended environments presents both opportunities and challenges. By embracing effective pedagogical strategies, leveraging emerging technologies, and addressing potential barriers, educators can create engaging and effective learning experiences that equip students with the essential CAD skills needed for success in the modern engineering workforce. Further research is needed to explore the long-term impact of these approaches on student learning outcomes and to develop the best practices for online CAD education.

III. METHODOLOGY

Laboratory courses were identified as indicated in table I in which problems were faced while taking online practicals during COVID-19 pandemic, analyzed and selected for the Best Practices activity for the academic year 2021-22.

Laboratory Identification: The laboratory was identified through faculty’s brainstorming as given in Table I.

Out of 14 laboratory courses identified from Part-II of 2021-22, 8 laboratory courses were chosen based on the requirement of licensed software which is costly and students can’t install and practice on their laptop/desktop/mobile phones, availability of open source software for the development of Virtual Lab, ease of installation& ease of use by students on their mobile/laptop/desktop and availability of expert in the team to develop the Virtual Lab which are shown in table II

Laboratory Selection: After identifying the 8 laboratories as mentioned in table II, the Rating method was used on the categorized problems for selecting the problem with each member rating on a scale of 1 to 5 where 1 or 2-representing less importance, 3-average importance, 4-high importance and 5- very high importance.

After collecting the individual rating of each member for each problem, the aggregate rating is considered for problem selection. From the ratings provided in Table III, the Student’s online teaching-learning problem & requirement of CAD modelling skill of laboratory course was identified as a problem to be handled under best practices activity for the year 2021-22 which has scored the highest aggregate rating.

The best way for students to understand engineering concepts is through hands-on laboratory experiments. The COVID-19 pandemic has brought uncertainty in educational response, skilling methods, and training practices among teachers and institutions. In the context of suspended face-to-face teaching, a virtual laboratory is a powerful educational tool that ensures the continuity of teaching and learning. It provides alternative ways for skills training from home. Because of the pandemic situation, there is a need to develop virtual labs in engineering education. In the Mechanical Engineering Department, Students and faculty members have faced more difficulties while delivering the modeling software, as students did not have sufficient facilities for the laptop, PC, Internet connectivity, and license copy of the software.

The student's engagement in laboratory courses beyond the classroom is influenced by several factors that must be addressed collectively. The information presented in Figure 1 was collected using the 4W-1H principle to identify the causes of poor engagement beyond the classroom. These causes were identified through brainstorming, analyzed, and categorized into those related to students, faculty, and the environment.

TABLE I
LABORATORIES IDENTIFIED

Sr No	Laboratory Course Name	Class
1	Microcontroller Lab	SY B Tech (Mechatronics)
2	CAD Modeling Lab	SY B Tech (Mechatronics)
3	Kinematics & Dynamics of Machines Lab	SY B Tech (Mechatronics)
4	Object Oriented Programming Lab	SY B Tech (Mechatronics)
5	Workshop Practice-II	SY B Tech (Mechatronics)
6	Applied Thermodynamics Lab	SY B Tech (Mechanical)
7	Machine Drawing Lab	SY B Tech (Mechanical)
8	Computer Programming C++ Lab	SY B Tech (Mechanical)
9	Workshop Practice-II	SY B Tech (Mechanical)
10	Thermal Engineering Lab-III	TY B Tech (Mechanical)
11	NX-CAD	TY B Tech (Mechanical)
12	NX-CAM	TY B Tech (Mechanical)
13	MATLab	TY B Tech (Mechanical)
14	Software Development with C++	TY B Tech (Mechanical)

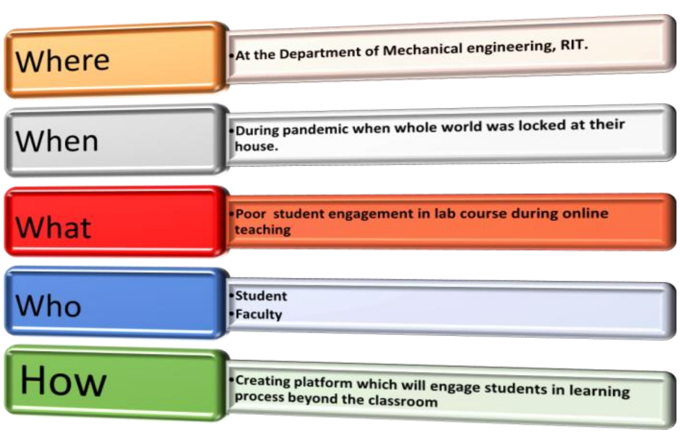

Fig. 1. Problem Analysis: 4W-1H principle

TABLE II
LABORATORY DETAILS

Sr. No:	Laboratory	Licensed Software Required	Availability of Open Source Software	Ease of installation by students
1	CAD Modeling Lab	Yes	Yes	No
2	Object Oriented Programming Lab	No	Yes	Yes
3	Machine Drawing Lab	Yes	Yes	Yes
4	Computer Programming C++ Lab	No	Yes	Yes
5	NX-CAD	Yes	No	No
6	NX-CAM	Yes	No	No
7	MATLab	Yes	No	No
8	Software Development with C++	No	Yes	Yes

TABLE III
RATING OF INDIVIDUAL TEAM MEMBERS FOR THE SELECTION OF LABORATORY

Sr. No	Problem	UMN	SBK	RAM	RVP	AKP	Total
1	**CAD Modeling Lab**	**5**	**5**	**4**	**5**	**4**	**23**
2	Object Oriented Programming Lab	3	3	4	4	4	18
3	Machine Drawing Lab	5	4	4	4	4	19
4	Computer Programming C++ Lab	5	4	3	3	4	19
5	NX-CAD	5	4	4	4	5	22
6	NX-CAM	3	4	4	3	3	17
7	MATLab	4	4	4	5	3	20
8	Software Development with C++	4	4	4	4	4	20

There are several causes for students' low involvement in online learning modes. Unsurprisingly, the online learning environment presents several problems and numerous benefits to student learning. Many authors have undertaken various research on this subject. The most often reported obstacles in the study literature fall into two major categories: challenges caused by a mismatch between students' individual learning style preferences and the online learning environment, and communication challenges. Concerning difficulties resulting from a mismatch between students' particular learning style preferences and the online learning environment.

Cause and Effect Analysis: The cause-and-effect diagram in Figure 2 expresses the reasons concerning students, faculty, and infrastructure. The text boxes under each category indicate the causes of students' poor engagement in online learning of practical courses.

Proposed Solutions: The following alternative solutions were proposed based on the route causes mentioned in the cause-effect diagram. They are:

1. Calling students to the laboratories in short batches during the COVID-19 pandemic.
2. Preparing lab videos using Assistants and sharing them with students.
3. Motivating students for self-learning.
4. Development of a virtual lab platform using available free sources and making it available for students to use it remotely.

The alternative solutions mentioned above were identified to improve the active engagement of students in learning the lab courses. From the rating method applied to alternate solutions, it was observed that all the solutions were necessary. Implementing any one solution may not result in the improvement of learning in virtual mode. The alternate solution: “Development of virtual lab platform using available free sources and making it available for students to use it remotely" gained the highest score.

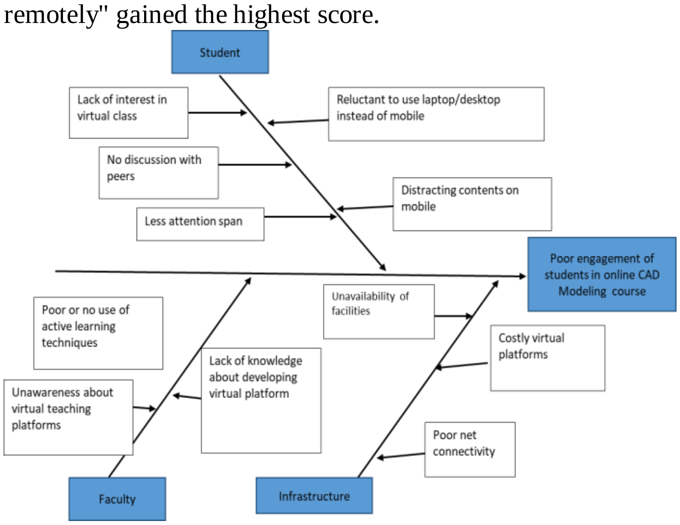

Fig. 2. Cause and Effect Analysis

TABLE IV
ATING OF INDIVIDUAL TEAM MEMBER ON ALTERNATE SOLUTIONS.

Sr. No	Problem	UMN	SBK	RAM	RVP	AKP	Total
1	Calling students to the laboratories in short batches during COVID-19 pandemic.	4	4	4	4	5	21
2	Preparing lab videos using Assistants and sharing with students.	5	4	4	5	5	23
3	Motivating students for self-learning.	4	4	4	4	4	20
4	**Development of virtual lab platform using available free sources and making it available for students to use it remotely.**	**5**	**5**	**5**	**5**	**5**	**25**

IV. FINDINGS AND DISCUSSION

A. *Implementation of the Virtual CAD Lab:*

To solve the problems of teaching online lab courses, it was decided to develop Virtual Lab for CAD Modeling Lab course by forming a team of faculties from the Mechanical Department under the best practices activity of Quality Circle. Throughout the development of the Virtual Lab, we strategically assigned tasks to team members to ensure smooth coordination. This approach facilitated a well-organized and efficient workflow, ultimately leading to accelerated progress and the delivery of high-quality output Figure III shows the flow chart for developing Virtual Laboratory using the open-source software Free CAD. The activities proposed are progressive and iterative. The development of a Virtual Laboratory includes data collection, resources available, testing and implementation.

Website Development in WordPress Open-Source Software: Website "https://ritvirtualcad.wordpress.com/ " is developed in WordPress which is also open-source software for website development.

The website can be accessed from a desktop or laptop or mobile phone. The website has 6 buttons which are linked to their appropriate information as shown in Figure IV.

The website link was shared with 38 out of 77 students of the SY B Tech C3 & C4 batches of Mechatronics for online learning of FreeCAD software. The total number of students who visited the website https://ritvirtualcad.wordpress.com/ submitted pre-session quiz, learned CAD Modeling Experiments on FreeCAD and submitted post-session quiz is given below in Table No V.

The advantages of the virtual lab initiative are notably significant. Firstly, it ensures the Continuity of Learning by maintaining CAD education amidst pandemic-related disruptions, aligning with findings in the literature such as those by Mah- mood et al. (2021) and Brinson (2015), who highlight that virtual labs offer crucial access during unforeseen disruptions or when physical resources are constrained. Secondly, the high level of student engagement, evidenced by increased views and assignment submissions, underscores the virtual lab’s effectiveness in motivating students, a central objective in online learning environments as articulated by Al-Gindy et al. (2020). Despite these advantages, the initiative presents certain limitations. The limited Scope, with the virtual lab piloted for only a single course, suggests potential scalability challenges, a concern echoed in Al-Gindy et al. (2020) regarding the time-intensive nature of developing virtual labs. Additionally, while not explicitly stated, the absence of physical interaction with CAD equipment may be a disadvantage. Literature, including Al-Gindy et al. (2020), indicates that virtual labs, although beneficial, may not entirely substitute for hands-on experience, particularly in advanced stages of learning.

This study addresses an immediate and practical need for virtual laboratories, particularly in enhancing accessibility during periods of disruption, as supported by existing literature on the subject. The research underscores the significance of engagement, a well-documented challenge in online learning environments. However, a more thorough evaluation is required to juxtapose these findings with existing literature on how various design elements impact student engagement.

The study falls short in its critical analysis of potential drawbacks, such as scalability issues and the "realism" gap areas that are extensively discussed in the broader body of virtual lab research. A more comprehensive understanding would be achieved by explicitly addressing these potential disadvantages. Additionally, incorporating feedback from both students and instructors regarding the perceived strengths and weaknesses of the virtual lab, and conducting comparative analyses of learning outcomes between virtual and traditional laboratory settings, would provide a more nuanced evaluation of the virtual lab's effectiveness.

TABLE V
NUMBER OF STUDENTS WHO LEARNED FREECAD & SUBMITTED PRE-SESSION & POST-SESSION QUIZ

Exp. No	**Name of the Experiment**	**Pre-Session Quiz link**	**Pre-Session Quiz Submitted**	**Post-Session Quiz link**	**Post-Session Quiz Submitted**
1	**Sketcher part 1**: Drawing of Line, Triangle, Rectangle, Circle, Ellipse and other standard components.	**https://forms.gle/aeEnY6w6SAnYDTpY8**	30	https://forms.gle/z1wx9RuNJqRMrxVw9	30
2	**Sketcher part2** : Constraints: Dimensioning of the sketch, use of Geometrical constraints, dimensional constraints.	**https://forms.gle/CN5sU6TdxfiknqE16**	30	https://forms.gle/mYpsffmJ2yV5fV5y9	29
3	**Sketcher part3 :** Sketching of Industrial components	**https://forms.gle/CNfy6p7AycQbr4yM9**	28	https://forms.gle/v4YJxGnM157xSbU9A	29
4	**Part Design 1:** 3D Modeling basic commands	**https://forms.gle/oDfyQWW7zjDdKerm6**	29	https://forms.gle/9cTiECKisJWatxkm8	29
5	**Part Design 2:** Use of Transformation features for 3D Modeling	**https://forms.gle/Yn7QgfF5UpZtwdKt6**	28	https://forms.gle/Jb9ED2Q7WHXbRzJc9	27
6	**Part Design 3:** Creating 3D Model of Industrial component	**https://forms.gle/f9dtzYTnKDBeEjx99**	26	https://forms.gle/NXUULtKTfAhZsnRH8	29
		Average Students	**29**	**Average Students**	**29**

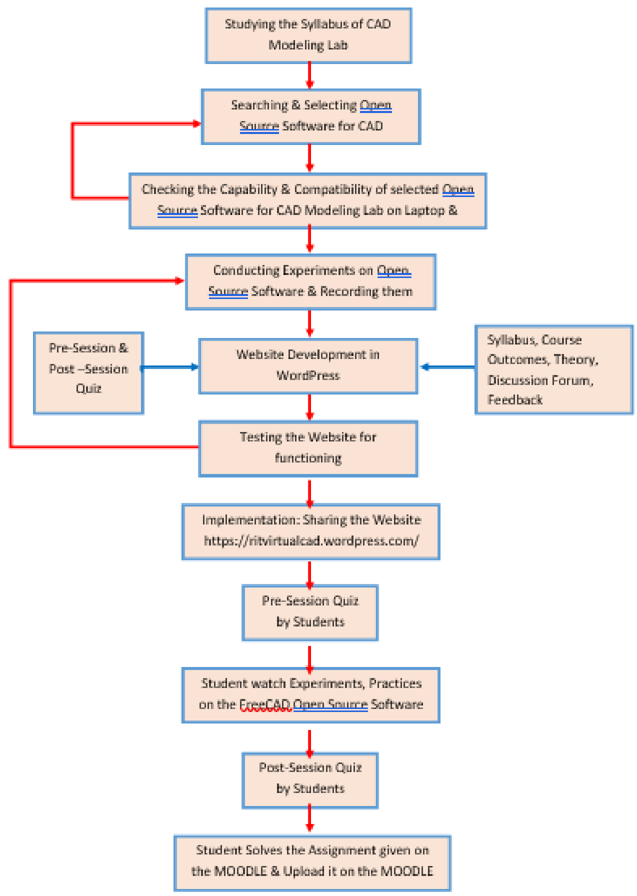

Fig. 3. Methodology for implementing proposed solution.

CONCLUSION

In conclusion, the implementation of the Virtual Lab for the CAD Modeling Lab course for the second-year Bachelor of Technology (B.Tech) Mechatronics program has demonstrated significant success. This success is evidenced by the attainment of a 100% online assignment submission rate and a total of over 1300 views, which underscores heightened student engagement and interest in the virtual laboratory. These outcomes confirm that the primary objectives of the initiative, namely, the development of an effective virtual lab for the software course and the evaluation of its implementation efficacy, have been satisfactorily met.

Looking forward, the Virtual Lab is slated for deployment in the third-year B.Tech Mechanical CAD Modeling Lab course, to extend its use to automobile engineering students and diploma candidates. Furthermore, there is potential for the virtual lab framework to be adapted for other software-based courses within the Mechanical Engineering curriculum. To maintain success and relevance, course experts must be part of the virtual lab development team. Their expertise will be crucial in refining the lab's functionality and ensuring that it meets the evolving needs of the students and the curriculum.

Fig. 4. Website home page

Fig. 5. Assignment Submission status on the moodle

REFERENCES

Syllabus of SY B Tech Mechanical, SY B Tech Mechatronics & TY BTech Mechanical Part-II, 2021–2043. (2017).

Al-Gindy, A., Felix, C., Ahmed, A., Matoug, A., & Alkhidir, M. (2020). Virtual reality: Development of an integrated learning environment for education. International Journal of Information and Education Technology, 10(3), 171–175.

Attarbashi, Z. S., Hashim, A. H. A., Abuzaraida, M. A., Khalifa, O. O., & Mustafa, M. (2021). Teaching Lab-based Courses Remotely: Approaches, Technologies, Challenges, and Ethical Issues. IIUM Journal of Educational Studies, 9(3), 37–51.

Cavanaugh (2008). Analysis of the research, extroverted students. Journal of Advanced Academics, 662–712.

Davis, D. (2008). Online Education Forum Part Two - Teaching Online Versus Teaching Conventionally. Journal of Information Systems Education, JISE), 19, 157–164.

Dhandabani, L. & Sukumaran, R. (2014). Use of ICT in engineering education: A survey report. 2014 IEEE International Conference on Computational Intelligence and Computing Research, 1–5.

Kavade, M. V., Khot, S. B., & Telsang, M. T. (2017). Impact of IUCEE IGIP Engineering Educator's Certification Program on Teaching Performance of Participants. Journal of Engi- neering Education Transformations, 30(3), 2349–2473.

Khot, S. B., Jadhav, P. J., & Jadhav, P. M. (2020). Teaching engineering design module from Engineering Exploration and Design Project (EEDP) course through hands-on activities. Journal of Engineering Education Transformations, 33.

Khot, S. B., Patil, S. K., & Kulkarni, S. S. (2023). A novel way to designing the undergraduate mechanical engineering curriculum using active stakeholder participation. Journal of Engineering Education Transformations, 36.

Li, B. (2008). An overview of online education: attractiveness, benefits, challenges, concerns and recommendations. Publisher: Project Innovation Austin LLC, 42.

Liu, H., Xu, S., & Liu, S. (2021). An online course mode based on microlecture videos: Using CAD geometric modelling course as an example. Comput Appl Eng Educ, 29, 1300–1311.

Scalise, K., Timms, M., Moorjani, A., Clark, L., Holtermann, K., & Irvin, P. S. (2011). Student learning in science simulations: Design features that promote learning gains. Journal of Research in Science Teaching, 48(9), 1050–1078.