Journal of Engineering Education Transformations ,
Volume 36 , No. 3 , January 2023 , ISSN 2349-2473, eISSN 2394-1707

10.16920/jeet/2023/v36i3/23107

Impact of Simulation-Based Teaching in the Development of Students' Exploration and Learning Skills

R.Priyakanth[1], N.M.Sai Krishna [2]

[1 2] BVRIT HYDERABAD College of Engineering for Women
[1] priyakanth.r@bvrithyderabad.edu.in
[2] saikrishnakumar.n@bvrithyderabad.edu.in

Abstract : Students in higher education, learn many courses in their curriculum, especially in various engineering streams. Not all the courses in the curriculum are accompanied by physical laboratories to have practical exposure. Some of the courses are restricted only to theory content. In this context, simulation-based teaching and learning make such courses more interesting and enhance student learning and interaction in classrooms even in online or offline teaching. For the courses that are supported by simulation software, the facilitator or instructor can apply the simulation-based training techniques, tools, and strategies in designing well-defined learning capabilities. As a part of the study, simulation-based teaching and learning was tested in delivering two courses online. One of them is a third-year course "Antennas and Propagation" wherein the "Antenna Designer" application in Matrix Laboratory (MATLAB) environment was used to ensure the students learn the performance of an antenna, based on various design parameters and the other one is a second-year course "Electronic Circuit Analysis" wherein "Multisim Live online simulator" was used for designing and analyzing the circuits. The participation and engagement of around 65 learners each year were examined by the way they performed the complete design and analysis in the respective courses. The student's performance was assessed based on the clear demonstration of design and analysis they performed. This experiment found that about 80% of students benefitted from the experiment in terms of what they learned and how well they could do analysis, in both courses. This method of simulation-based learning embedded with the instructional design helped the students enhance their exploration skills and hence supported learning new concepts.

Keywords : Student Engagement, Simulation-Based Learning, Short Demonstrations, Student Assessment, MATLAB, Multisim.

R.Priyakanth
BVRIT HYDERABAD College of Engineering for Women
priyakanth.r@gmail.com

1. Introduction

In many engineering streams, simulation is broadly described as a technological model that assists the facets of reality in delivering practical experiences and enhanced learning (Jamil,M.G., Isiaq, S.O., 2019). Utilizing the simulators in

engineering education as a teaching tool is extensive because simulations are identified as a successful way of teaching and learning complex and dynamic systems (Taher, M.T., & Khan, A.S., 2015). Such an ecosystem has the benefit of cutting costs for the practice-oriented educational system. With a motive of endorsing the direct involvement of students in developing their expertise, this method of simulation-based education provides an eco-system inducing the passion for hands-on learning under the supervision and guidance of facilitators or instructors (Campos, N., Nogal, M., Caliz, C. et al., 2020). Simulation-based training programs can certainly provide a constructive ecosystem to enhance the learning experience. Students can be offered a detailed and explicit assessment of the direct positive effect of such experiential learning through simulation (Albachiara Boffelli et al., 2021). The student performance depends on the duration of the simulation. This duration states the time of student exposure to a learning environment (Olga Chernikova et al., 2020). Simulation-based learning needs to be merged into an organized program making the process of learning more experiential (Manuaba Amertha et al., 2020).

2. Simulation-based Learning

A Simulation is an approach for practice and learning that can be applied to various disciplines. It is a proxy mode to reinstate and enhance real experiences with piloted ones, that imitate significant attributes of the real world in a fully interactive manner (Hong, J. et. al, 2022). The simulation-based training provides the instructions of real-world circumstances, helps to analyze the content, and hence reduces the barrier between the online or offline learning ecosystem and the real-world environment (Almasri, F, 2022). Simulation-based instruction not only enriches the students' performance but also transforms their routines hence improving expertise and delivering the best skills (Abdullah Alenezi, 2019). The integration of online simulation along with concept mapping is operative in enlightening students' digital literacy skills (Riki Perdana et al., 2020). Simulation can be said as one of the technologies that enhanced learning methods providing group reflections, integrating both theory and practice, and creating new prospects for exploratory challenging cases (Maria Zenios, 2020). The simulation process not only helps in the course delivery but also can discover a viable number of complications and govern optimal parameters increasing the likelihood of building the prototype on the initial effort (Paul Cepeda et al., 2014). For electronics and communication engineering students, simulators are a remarkable alternative, though cannot substitute real experimentations with electronic components, telecommunication devices, and apparatus, counting real environments (Carlos Alexandre and Gouvea da Silva, 2018).

Simulation-based teaching in the course "Antennas and Propagation", visually interprets the design of various antennas and helps in analyzing the antennas' performance by varying the required antenna design parameters. Re-enactment innovation creates the examination of electronic circuits that can be precisely and immediately finished in Multisim helps the students to learn various concepts in the course "Electronic Circuit Analysis". Various courses in all disciplines are well supported by the simulation eco-system, provided there exists software that is needed for simulating the concepts.

3. Experimental Study On Impact

A. Case Study - 1

As a part of the study, in delivering the course "Antennas and Propagation" using Simulation, "Antenna Designer" application in MATLAB environment was used. This course is a part of the third year of electronics and communication engineering. The participation and engagement of about 65 learners belonging to the 2018 batch were examined by the way they have performed the complete design and analysis of the antenna using the "Antenna Designer" application in MATLAB.

The course "Antennas and Propagation" consists of the design of various antennas and analyzing their performance by varying the antenna specifications. The course involved the design and performance analysis of various antennas like linear, loop, parasitic, helical, horn, patch, and reflector. The

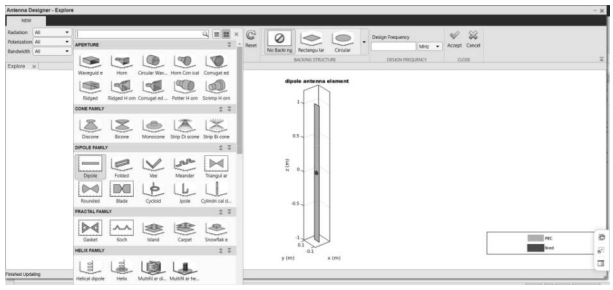

Fig. 1: Antenna Designer application in MATLAB (R2021a)

"Antenna Designer" application in MATLAB provides a platform for making an optimal design for the selected antenna as shown in Fig. 1. As a part of instructional and learning activities, students were assigned tasks individually to design a specific antenna and demonstrate the observed variations in the antenna performance by varying the properties of the respective antenna. The application also provides the option of making the antenna design more desirable or optimal by maximizing the gain, bandwidth, etc.

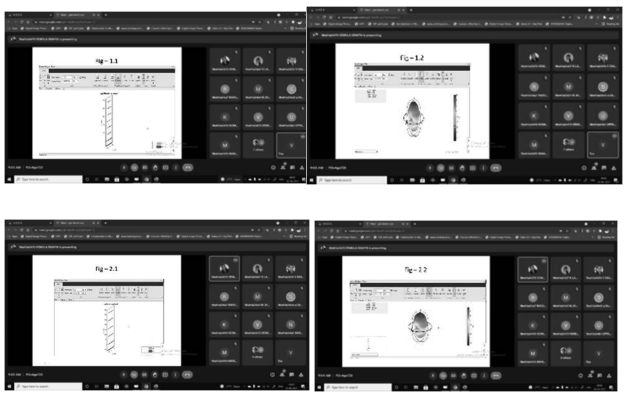

Fig. 2: Student Demonstrations of Yagi-Uda Antenna Design and Analysis using Antenna Designer application ntenna Designer application in MATLAB (R2021a)

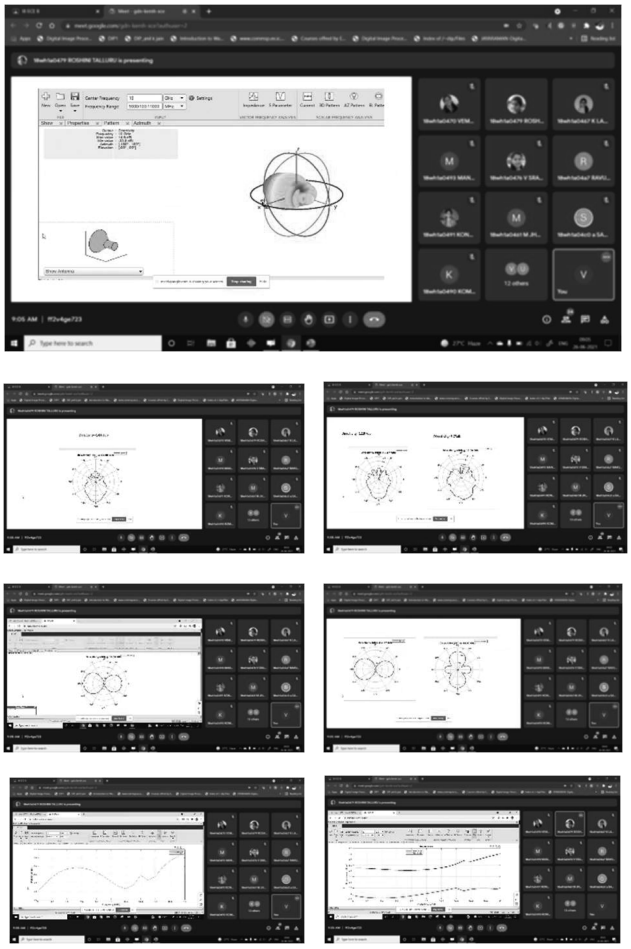

Fig. 3 : Student Demonstrations of Conical Horn Antenna Design and Analysis using Antenna Designer application

With the freedom of varying the antenna parameters, students followed a holistic approach in designing the antennas for optimal performance. As the course instruction was done online, all the students were given chance to demonstrate the antenna design and analysis using the "Antenna Designer" application in MATLAB by sharing their screens online.

The short demonstrations of Yagi-Uda antenna, Conical Horn antenna, and Patch antennas are presented as some examples in Fig. 2, 3, and 4 respectively

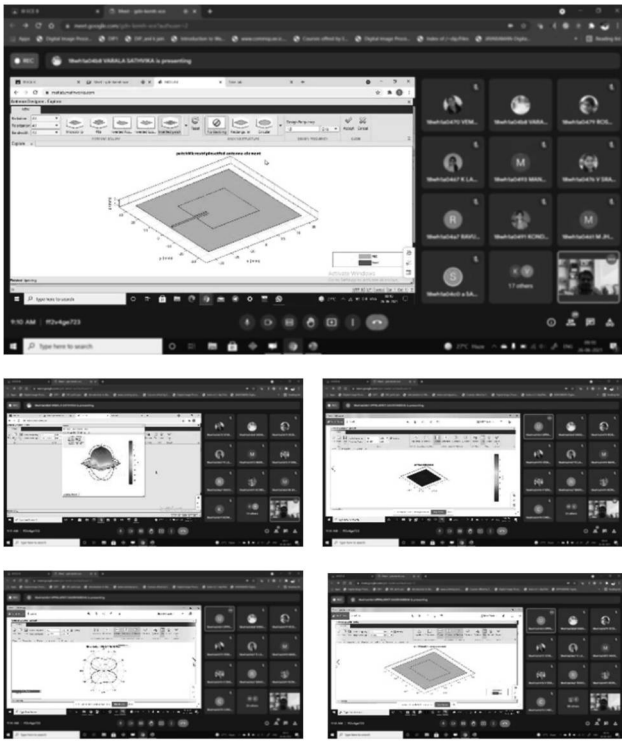

Fig. 4: Student Demonstrations of Patch Antenna Design & Analysis using Antenna Designer application

The individual assessment was done based on the students' ability in presenting a short demonstration, record their reflections, and write an explanation based on the observations. Rubrics or formalized assessment scales shown in Table 1, for a total of 20 marks were applied to score student demonstrations and observations. This process also promoted class discussion during the demonstrations. The

Table 1 : Rubrics To Assess Student Demonstrations & Observations (course: Antennas And Propagation)

Criteria	No Credit (0 Marks)	Emergning (1 Mark)	Developing (2 MARKS)	Proficient (3 Marks)	Exemplary (4 Marks)
Background Knowledge in Antennas	No related knowledge of antennas	Have only the minimal knowledge about the antenna design. No knowledge in analysis	Have the minimal knowledge about the antenna design and analysis using only limited specifications	Have the required knowledge about the antenna design and analysis using required specifications	Have the complete knowledge about the antenna design and analysis using all specifications
Knowledge in Antenna Designer application in MATLAB	No knowledge in Antenna Designer application	Have the minimal knowledge about how to use Antenna Designer application.	Have the required knowledge about how to use Antenna Designer application for Design only	Have the required knowledge about how to use Antenna Designer application for normal Design and analysis	Have the complete knowledge about how to use Antenna Designer application for optimal Design and Analysis
Antenna Design and Analysis	Cannot perform the antenna design	Can Perform the Design only for one or two antennas.	Can Perform the Design only for more than two antennas in curriculum. and can do optimal design with only one parameter	Can Perform the Design and Analysis for any antenna in curriculum. But cannot do optimal design	Can Perform the optimal Design and Analysis for any antenna in curriculum
Critical Thinking	Doesn't know that the antenna design can be optimized	Know what optimization is. But cannot perform the same in Antenna Designer application	Know about antenna optimization and performed with only one parameter	Know about antenna optimization and performed with only two parameters	Optimization of antenna design is performed with change in all required parameters
Presentation Skills	Presenter talks very fast. Speaks too quietly and majority of students cannot hear or understand	Presenter's voice is low. The pace is much too rapid/slow. Audience have difficulty in hearing presentation	Presenter's voice is clear at times. Most audience can hear presentation but with less difficulty	Presenter's voice is clear. The pace is little slow or fast at times. Most audience can hear presentation.	Uses a clear voice and speaks at a good pace so audience can hear presentation. Pointing options were used wherever required

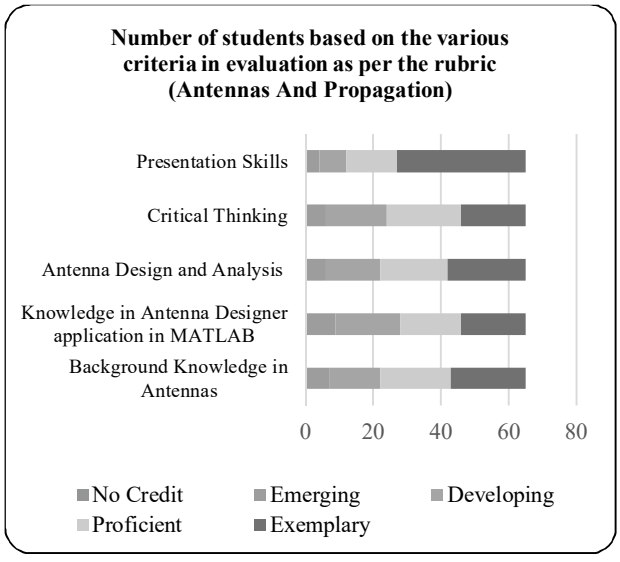

Fig.5 : Assessment of Short Demonstrations (Antennas and Propagation)

performance of students assessed using the rubrics for short demonstrations was recorded. It was observed that the students performed well in the short demonstration activity as shown in Fig. 5. The experimental results have shown that the students have actively participated in the simulation-based design and analysis of various antennas showing the improvement in student engagement in online classes. Also, it was observed from the evaluation of the short demonstrations using the designed rubrics that around 70 percent of the students were into the proficient and exemplary levels directly indicating the increase in the levels of exploration and learning skills.

Post-intervention (Caroline Koh et al., 2013) of simulation-based learning, the students were also assessed in their mid-term examinations subjectively. The increase in the application of content knowledge was observed in the form of an increase in the performance of students in mid-2 term examinations compared to mid-1. The enhancement in students' performance is shown in Fig. 6.

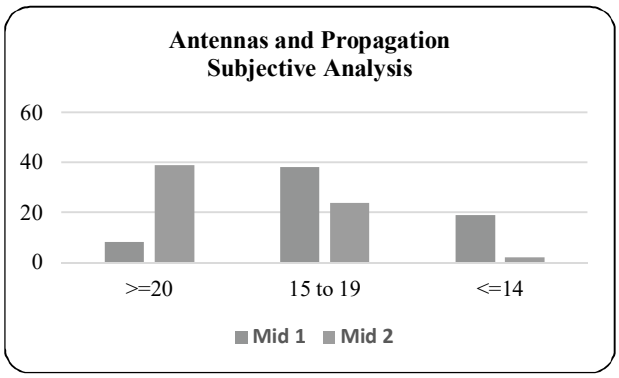

Fig. 6: Subjective Assessment – Antennas and Propagation (Mid Marks)

The grades that these students in the course Antennas and Propagation received at the end of the semester support the findings from this study depicted in Fig. 7. In this student batch, about 80% of the students in this course got a grade of 7 or above. That's more than double last year's number.

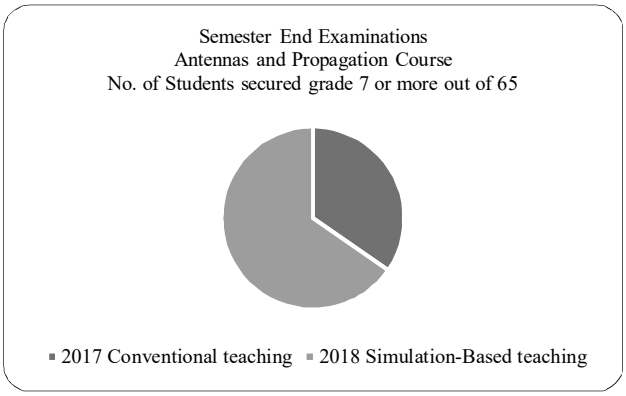

Fig. 7: External Assessment – Antennas and Propagation (Semester End Examinations)

B. Case Study - 2

As a part of the study, in delivering the course "Electronic Circuit Analysis" using Simulation, "Multisim Online" was used. This course is a part of the second year of electronics and communication engineering. The participation and engagement of about 65 learners belonging to the 2019 batch were examined by the way they have performed the complete design and analysis of electronic circuits using the "Multisim Online".

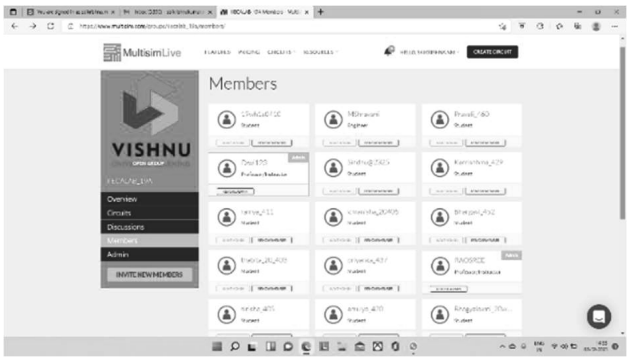

Fig. 8 : Students enrolled into Multisim Live

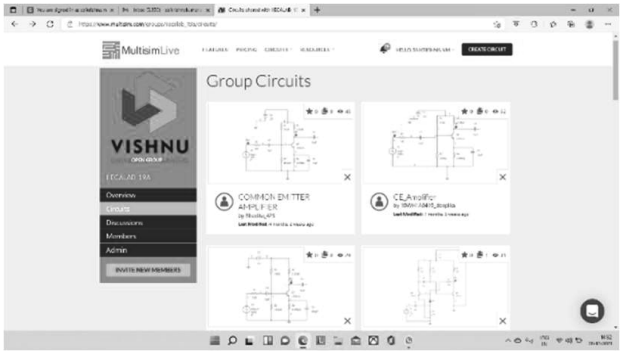

Fig. 9: Circuits designed by various students based on a single concept

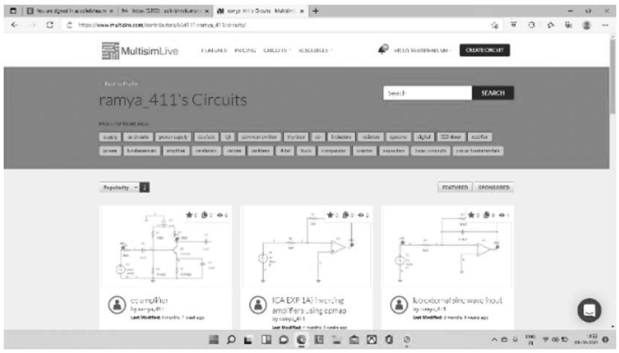

Fig. 10 : Circuits designed by a student

Table 2 :Rubrics To Assess Student Demonstrations & Observations (course: Electronic Circuit Analysis)

Criteria	No Credit (0 Marks)	Emergning (1 Mark)	Developing (2 MARKS)	Proficient (3 Marks)	Exemplary (4 Marks)
Background Knowledge in Circuits	No backgrou-nd knowledge of Circuits	Have only the minimal knowledge about Multisim circuits. No knowledge in analysis	Have the minimal knowledge about circuit connections.	Have the required knowledge about design and simulating circuits	Have the complete knowledge about design and simulating circuits using all specifications
Knowledge in Circuit Simulation in MULTISIM Online	No knowled-ge in Multisim LIVE	Have the minimal knowledge about how to connect the circuit using Multisim Online.	Have the required knowledge about how to connect the circuit using Multisim Online.	Have the required knowledge about how to connect the circuit using Multisim Online.	Have the complete knowledge about how to connect the circuit using Multisim Online.
Circuit Design and Analysis	Cannot perform the Circuit Design	Can Perform the Design only for one or two circuits .	Can Perform the Design for different combinations of biasing and can do best design with only one parameter	Can Perform the Design and Analysis for any circuit in curriculum. But cannot do best design	Can Perform the best Design and Analysis for any circuit in curriculum
Critical Thinking	Doesn't know that the circuits design can be optimized	Know what optimization is. But cannot perform the same in designing the circuits	Know about circuit optimization and performed with only one parameter	Know about circuit optimization and performed with only two different biasing elements	Optimization of circuit design is performed with change in all required parameters
Presentation Skills	Presenter talks very fast. Speaks too quietly and majority of students cannot hear or understand	Presenter's voice is low. The pace is much too rapid/slow. Audience have difficulty in hearing presentation	Presenter's voice is clear at times. Most audience can hear presentation but with less difficulty	Presenter's voice is clear. The pace is little slow or fast at times. Most audience can hear presentation.	Uses a clear voice and speaks at a good pace so audience can hear presentation. Pointing options were used wherever required

The Multisim Online portal has the option of adding the entire on the students' ability in presenting a short demonstration and their reflections. The same process of assessment was followed as in case study-1 based on rubrics shown in Table 2. A total of 20 marks were applied to score student demonstrations and observations.

Similar to Case Study-1 it has been found that around 70 percent of the students were into the proficient and exemplary levels directly indicating the increase in the levels of exploration and learning skills as shown in Fig.11.

Similar to case-1, after using the simulation-based teaching and learning method, the students were also assessed in their mid-term examinations subjectively. The enhancement in students' performance is shown in Fig. 12.

The grades that these students in the course Electronic Circuit Analysis received at the end of the semester support the findings from this study depicted in Fig. 13. In this student batch, about 75% of the students in this course got a grade of 7 or above. That's nearly double last year's number.

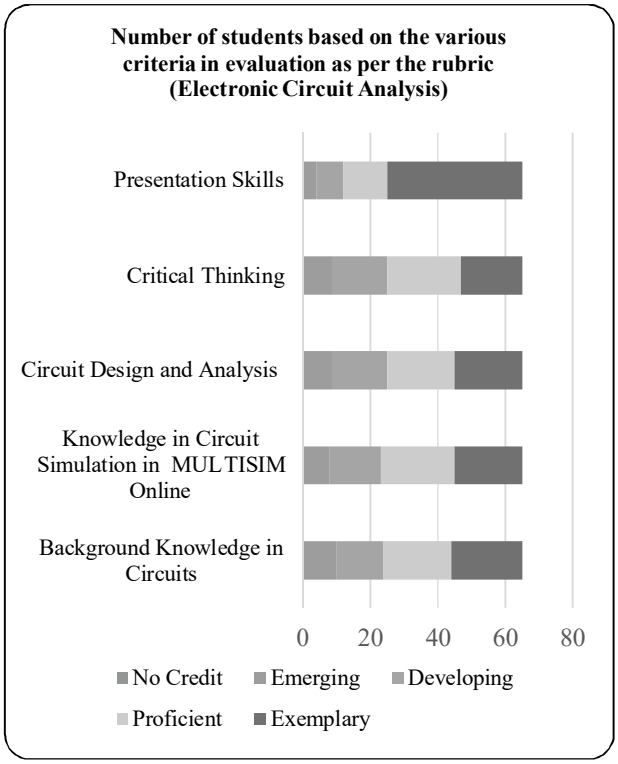

Fig. 11 : Assessment of Short Demonstrations (Electronic Circuit Analysis)

As a part of the study on simulation-based teaching and learning, qualitative feedback was collected asking students to rate the process on a scale of 1 to 10. The feedback from the beneficiaries reported that more than 80% of students were able to correlate the concepts in both the courses with the process of simulation and were able to perform the required analysis. The qualitative feedback is summarized as shown in Fig. 14 and 15 for the courses "Antennas and Propagation" and "Electronic Circuit Analysis" respectively.

Hence, this method of simulation-based teaching and learning improved the student engagement and learning capabilities and hence critical thinking with the help of design and analysis in the courses "Antennas and Propagation" and "Electronic Circuit Analysis" using respective simulation software.

This simulation-based eco-system can be extended to the majority of engineering courses that are supported by various simulation software. These types of simulations can also be used to complete course projects (Asgari S et al., 2021). Regardless of the substantial benefits in learning outcomes emphasized in this paper, the high cost of designing simulations will always be a noteworthy challenge (Dimitrios Vlachopoulos and Agoritsa Makri, 2017).

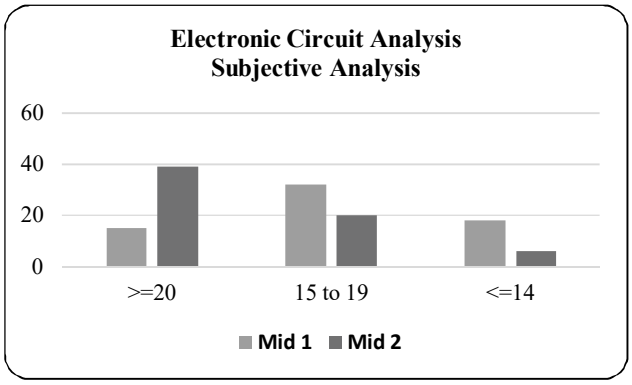

Fig. 12. Subjective Assessment – Electronic Circuit Analysis (Mid Marks)

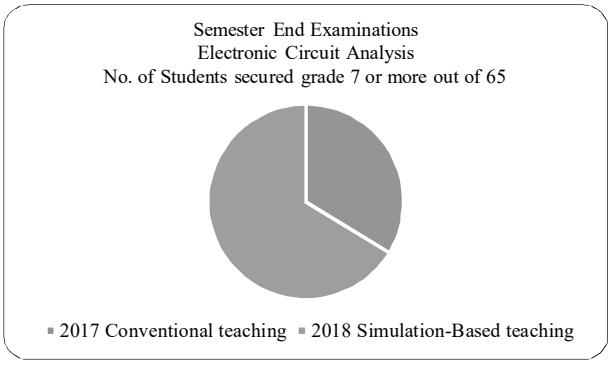

Fig. 13: Opinion on the activity

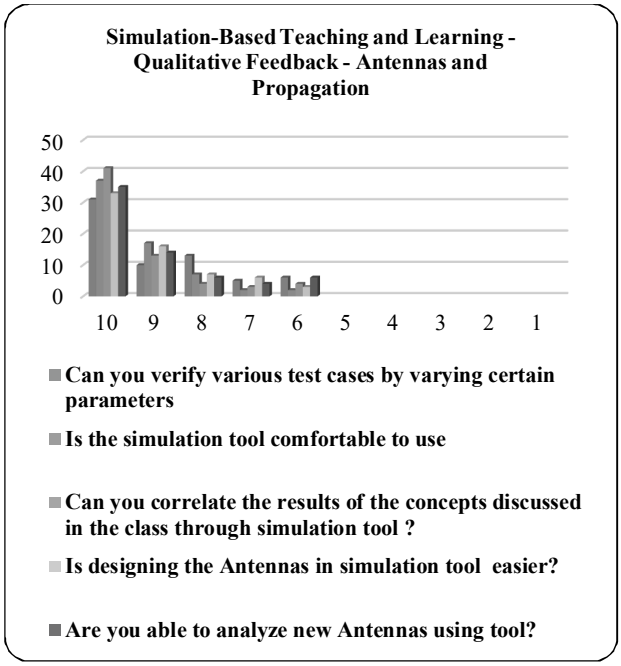

Fig. 14 : Qualitative Feedback (Antennas and Propagation)

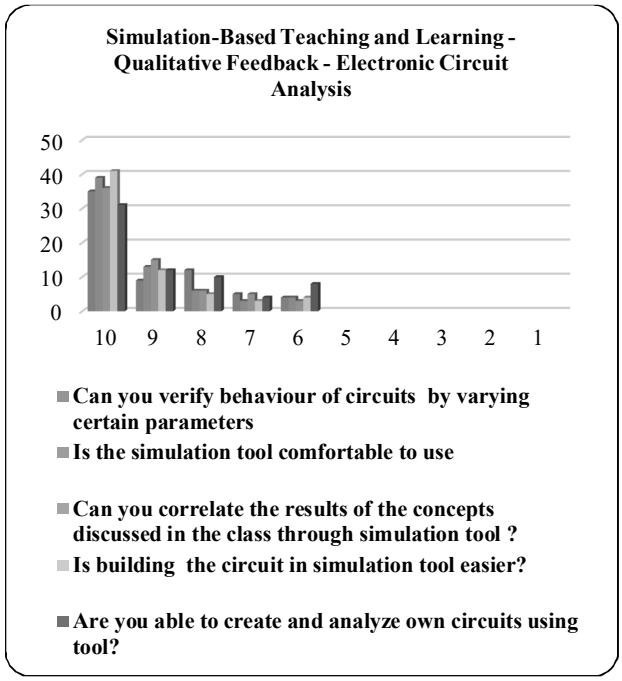

Fig. 15: Qualitative Feedback (Electronic Circuit Analysis)

4. Conclusions

In this paper, the importance of the study of simulation-based teaching and learning in engineering education was detailed with the delivery of the "Antennas and Propagation" course. Also, the experimental study on the impact of simulation-based teaching in the development of students' exploration and learning skills was performed. It was observed that this method also enhanced student engagement in online or offline classes. The study results supported our idea on the positive and constructive effects of simulations in delivering various engineering courses. The outcome of this approach encourages the facilitators to support such learner-centric demonstration activities. Finally, this study recommends the use of a simulation-based eco-system inducing the passion towards hands-on learning under the supervision and guidance of facilitators or instructors.

ACKNOWLEDGMENT

We are very grateful to the Principal and Management of Sri Vishnu Educational Society for providing us various opportunities to learn new tools required for blended learning, nominating us to attend the six-week IUCEE Online Teaching Course in the year 2020 during the pandemic. We are unceasingly working towards enhancing engineering education. I sincerely concede my gratitude for the collaborative work from my co-author.

References

[1] Jamil, M.G., Isiaq, S.O. (2019). Teaching technology with technology: approaches to bridging learning and teaching gaps in simulation-based programming education. International Journal of Educational Technology in Higher Education, 16(1).

[2] Taher, M., & Khan, A. (2015). Comparison of simulation-based hands-on teaching methodologies on students' learning in an engineering technology program. Qscience Proceedings, 2015(4),58.

[3] Campos, N., Nogal, M., Caliz, C., & Juan, A. A. (2020). Simulation-based education involving onlne and on-campus models in different Europian universities. International Journal of Educational Technology in Higher Education, 17(1).

[4] Bofelli, A., Kalchschmidt, M., & Shtub, A. (2020). Simulation-Based Training: From a traditional course to remote learning - the COVID-19 effect. Higher Education Studies, 11(1),8.

[5] Chernikova, O., Heitzman, N., Stadler,M., Holzberger, D., Seidel, T., & Fischer, F. (2020). Simulation-based learning in higher education: A meta-analysis. Review of Educational Research, 90(4), 499-541.

[6] Putra Manuaba, I. B.A., Dewi, N.G. A. P. L. S., Prabawa, I. P. Y., Bhargah, A., Darmayani, S., & Wu, C.-C. (2020). Simulation-based learning compared with conventional methods in procedural skill. Indonesia Journal of Biomedical Science, 14(2), 86.

[7] Hong, J.-C., Liu, X., Cao, W., Tai, K.-H., & Zhao, L. (2022). Effects of Self-Efficacy and Online Learning Mind States on Learning Ineffectiveness during the COVID-19 Lockdown. Educational Technology & Society, 25(1), 142-154

[8] Amlasri, F. (2022). Simulations to teach science subjects: Connections among students; engagement, self-confidence, satisfaction, and learning styles. Education and Information Technologies, 27(5), 7161-7181.

[9] Alenezi, A. (2019). The impact of simulation on teaching effectiveness and student learning performance. International Journal on Integrating Technology in Education, 8(3), 1-11.

[10] Perdana, R., Jumadi, J., Rosana, D., & Riwayani, R. (2020). The Online Laboratory Simulation with Concept Mapping and Problem Based Learning(OLS-CMPBL): Is it effective in improving students' digital literacy skills?. Jurnal Cakrawala Pendidikan, 39(2), 382-394.

[11] Zenios, M. (2020). Educational theory in technology enhanced learning revisited: A model for simulation-based learning in higher education. Studies in Technology Enhanced Learning, 1(1).

[12] Cepeda, P., Ponce, P., & Molina, A. (2014). Simulation to implementation as good practices for teaching Power Electronics to undergraduate students: Fuzzy Sliding Mode Control for DC motors. Advances in Power Electronics, 2014, 1-9.

[13] Gouvea da Silva, C. A., Santos, E. L. dos, & Pelacini, D. A. F. (2018). Evaluation of academic experience in learning education over simulators softwares. International Journal on Alive Engineering Education, 5(2), 23-40.

[14] Caroline Koh. et al., (2013). Investing the Effect of 3D Simulation Based Learning on the Motivation and Performance of Engineering Students. Journal of Engineering Education. 99(3), 233-257.

[15] Asgari, S., Trajkovic, J., Rahmani, M., Zhang, W., Lo, R.C., & Sciortino, A. (2021). An observational study of engineering online education during the COVID-19 pandemic. PLoS One, 16(4), e0250041.

[16] Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: a systematic literature revieww. International Journal of Educational Technology in Higher Education, 14(1).