Integrating Next-Gen Learning Environments (NGLE) into Signals and System Engineering Education

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***Abstract*—The course Signals and Systems (SS) is a challenging course, and active teaching-learning activities still necessitate methods of conveying multifaceted concepts to undergraduates. One of the primary hurdles in the teaching-learning activities of this course is the involvement of advanced and complex mathematics. Addressing the challenges in teaching the SS course and familiarizing to the new dynamics of outcome-based education (OBE), a blended teaching model integrating the next-gen learning environment (NGLE) is proposed. This model combines traditional classroom instruction, teaching-learning activities, and the extensive practice of next-generation learning tools. To ensure a high standard of teaching-learning activity, a multi-dimensional assessment system was developed. Various real-time examples and questionnaire data demonstrated that NGLE successfully integrates in-class and out-of-class activities, as well as online and offline methods. This approach enhances students' engineering application skills, self-directed learning abilities, teamwork and communication skills, and nurtures innovative thinking. Comparisons between the traditional and improved teaching modes reveal that NGLE significantly improves teaching effectiveness, with a notable increase in excellent grades and a significant reduction in failure rates. This model serves as a valuable reference for enhancing the class-room instruction quality of engineering courses and maintains practical consequence.**

***Keywords*—Signals and systems; engineering education; outcome-based education; Next-Gen learning; teaching-learning.**

ICTIEE* Track*: Technology Enhanced Learning
ICTIEE Sub-Track: Next-Gen Learning Environments: Integrating AI for enhanced education

I. INTRODUCTION

THE rapid development of technology has significantly influenced educational methodologies, particularly in engineering education. The integration of Next-Gen Learning Environments (NGLE) in engineering courses, such as Signals and Systems (SS), promises to improve the learning experience by utilizing digital tools and platforms. Signals and systems, a fundamental course in electrical engineering and allied engineering branches, presents unique challenges due to its reliance on advanced mathematical concepts and complex theoretical frameworks. Traditional teaching methods often fall short in engaging students and effectively conveying these intricate concepts. Hence, there is a compelling need to explore innovative teaching strategies that can bridge this gap and improve student outcomes.

The SS course content involves complex mathematics topics like transforms and Fourier analysis. In conventional teaching, instructor delivers and demonstrates these topics by solving examples or two. However, due to lack of retention capability, most of the students fail to grasp all of these. Teaching signals and systems course without employing mathematics become non-effective and not meaningful. At the same time teaching just the concepts and normal mathematical approach will not be enough for students to get familiar with the behavior of different signals. In professional course, the practical sessions are to verify theoretical concepts learned in the classroom through laboratory experiments, simulations or emulations. To support the theoretical concepts taught in the class-room, practical or hands-on sessions should be conducted to strengthen the learning.

The literature shows that students retain only 25% of what they hear in the class-room, along with this, if they see, retention level increases up-to 45%, and if they apply and do i.e. experiential learning method, then it reaches up-to 70%, so emphasis on experiential learning of SS is vital (Rickel 1989, Patil 2021, Reddy 2024). Though laboratory or practical are very effective means of communicating the theory concepts and verifying the same, they have some limitations like cost,

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maintenance, demonstrator, safety, calibration and characteristics of real equipment. These limitations made to think of simulation platform, a substitute to real-time experiments. In academia and core industry, MATLAB-Simulink is most commonly used software simulation tool. It allows students to build system models, apply inputs, and observe the responses visually through graphical simulations and thereby analyzing the systems.

A method that merges conventional in-person teaching with online learning activities known as blended learning, has been extensively implemented in higher education and particularly for teaching SS course (Dou, Wang et al. 2023). According to Graham (2013), blended learning offers a flexible approach that can cater to diverse learning styles and paces, making it an effective pedagogical model. Literature study shows that blended learning can enhance student engagement, improve comprehension, and foster autonomous learning (Means et al., 2010). Kaur et al. (2023) employed SS Concept Inventory (SSCI), which reveals a strong correlation between high conceptual knowledge and excellent academic performance, while identifying specific challenges in convolution and Fourier analysis. The integration of NGLE, which encompasses advanced digital tools, interactive simulations, and collaborative platforms, further extends the potential of blended learning in engineering education. Educational technology has seen remarkable growth, with tools such as virtual laboratories, simulation software, and interactive modules becoming integral to modern education. McGrath et al. (2014) highlighted that virtual labs and simulations allow students to experiment with complex systems in a controlled, risk-free environment, enhancing their practical understanding. Additionally, interactive learning platforms like MOOCs and online discussion forums have democratized access to quality education, providing students with resources beyond the traditional classroom setting (Aswath 2023, Kop & Hill, 2008). The application of NGLE in engineering education has shown promising results. For instance, Cheng et al. (2017) demonstrated that using simulation software in teaching SS course improved students' conceptual understanding and problem-solving skills. Similarly, Sheth et al. (2019) reported that integrating online collaborative tools in project-based learning environments enhanced students' teamwork and communication abilities, which are critical competencies in engineering.

The literature studies emphasize the benefits of integrating digital tools in engineering education, there is limited research specifically addressing the implementation of NGLE in SS courses. The proposed research seeks to address this gap by introducing a detailed framework for integrating NGLE into the Signals and Systems curriculum. The main contributions of this research are to:

1. Develop a blended teaching model that incorporates NGLE for Signals and Systems education.
2. Evaluate the effectiveness of this model in improving student learning outcomes, including conceptual understanding, practical skills, and collaborative abilities.
3. Compare the proposed model with traditional teaching methods to assess its impact on teaching effectiveness and student performance.

The structure of the article is as follows: Section 2 describes traditional teaching-learning approaches, the use of simulation tools, and assessment methods. Section 3 presents the outcomes of the methodology employed to enhance student learning. Lastly, Section 4 concludes by highlighting the advantages of using interactive tools.

II. METHODOLOGY

A. Conventional Teaching – Learning

Second-Year undergraduate students in the Department of Electrical Engineering take the three-credit, one-semester SS course. It includes study of continuous-time (CT) and discrete-time (DT) signals and linear-time invariant systems. Earlier practice for teaching this course was based on theory concepts and few numerical approaches with chalk-talk and power-point slides. The assignments were given to support classroom teaching. The results showed the declination in success rate also unable to apply the learned concepts in the further semester courses like digital signal processing or control systems. The research in this field has shown that there is need to introduce interactive tools in teaching-learning process for improving success rate. It is reported that students' ability for problem solving and analysis has increased (Metri, et al. 2018; Pulavarthi, et. al. 2017). For teaching the SS course, numerous researchers have explored and reformed various teaching methodologies. For instance, to enhance understanding of SS course concepts, some researchers have implemented concept learning methods, achieving notable success (Dutta Roy and Dutta Roy 2018). Other researchers have employed team collaboration and peer learning techniques to inspire and motivate students' interest, foster teamwork, and improve teaching outcomes (Yang and Hu 2011, Velchev, Dimitrov and Laskov 2020). To elucidate signal applications, Luo used case teaching methods involving biological signal denoising in signal processing education (Luo 2019). José and Kemel introduced a calculus-based approach to deliver a new analytical view for SS course, which helped students better grasp convolution problems in SS course (José and Kemel 2020). The literature also shows that teaching methods based on different tools and approaches, such as programming, multimedia tools and MATLAB-assisted instruction are used (Da-you, Ni et al. 2019).

B. NGLE Environment

The methodology for integrating Next-Gen Learning Environments (NGLE) into the teaching of the Signals and Systems course involves a systematic approach to redesigning the course structure, incorporating digital tools, and evaluating the outcomes. This approach is divided into several key phases: course redesign, development and integration of NGLE tools, implementation, and assessment as shown in Fig. 1.

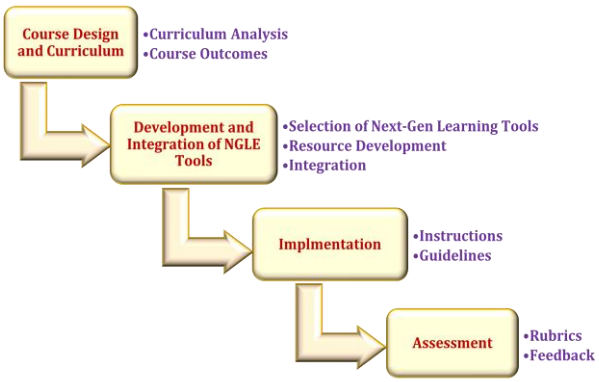


Fig. 1. A Framework of Next-Gen Learning Environment

1) Course Design and Curriculum

The SS course is designed considering the feedbacks from the stakeholders of Board of Studies (BoS) members, syllabus from GATE and industry requirements. The review of existing curriculum is carried out to identify the fundamental concepts that need to be covered, such as Fourier transforms, Laplace transforms, convolution, system stability and sampling. The course outcomes are defined and accordingly content is defined and same is discussed in the BoS meeting before finalizing the curriculum.

2) Development and Integration of NGLE Tools

The motive of this step is to develop and integrate digital tools that facilitate interactive and collaborative learning. Furthermore, to create resources that support activities both within and outside of the classroom for the students to enhance teaching-learning activities of SS course.

To implement the NGLE, various appropriate digital tools and platforms are selected. Moodle platform - a learning management system (LMS) is offered to organize course materials, assignments, and assessments instructions, rubrics and tutorials. The simulation software like MATLAB - Programming, Simulink, and Multisim are incorporated for visualizing and simulating signal processing and system behavior of different signals and systems. Moreover, to support students to understand complex problems, resource materials are uploaded on the LMS – Moodle. It included the sampled presentations, pdfs, hand-written solved problems and tutorials. Furthermore, interactive modules like Slido, Poll Everywhere, Kahoot etc. are also incorporated. Also, interactive diagrams animations and real-time simulations are included for the resource development. Virtual labs are introduced to student, where student can explore various courses experiments, test themselves through pre-and-post tests and visualize results.

3) Implementation

The implementation of any methodology for any course is a vital step in engineering education. Here, the blended learning model in a SS course is employed as shown in Fig. 2.

The teaching-learning activities for SS course is considering the millennial students, so planned accordingly various tasks through LMS – Moodle and various online internet activity tools. Some of the illustrative snaps from these platforms are shown in the Fig. 3. Initially based on the previous year result analysis and course content, the SS course plan is prepared. Also, taking into consideration, the In-Semester Evaluation (ISE) is planned, so the activities. For each unit of SS course, resource materials are uploaded in prior, along with the assignment questions. Furthermore, to test the students learning, an ISE was conducted with multiple choice questions. Then, while teaching Fourier series analysis online simulations are introduced to students to emphasize the notions. Also, MATLAB simulations are illustrated to showcase the different harmonic frequencies. In-line with this, an ISE was planned for students to program and simulate various content of the SS course. Some of the tasks assigned to students were, representation of various CT and DT signals; time dependent and independent operations on signals; operations of systems; Fourier series illustrations; Laplace transform solutions; finding Z-transforms; and illustration of Sampling theorem and aliasing effects. The open source online virtual labs are introduced to students to perform various experiments available on the platform, which helps them to understand the mathematics in terms of visualization or graphical manner. To demonstrate signal operations, their properties, system properties and sampling theorem '*Shakshat Virtual Lab'* developed by Indian

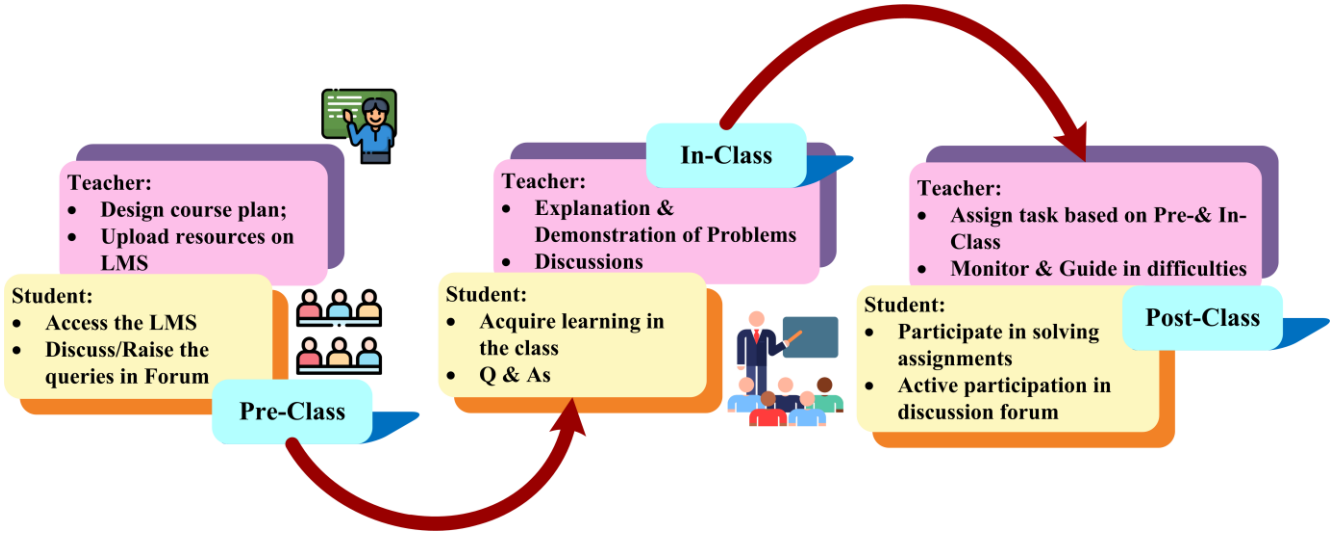


Fig. 2. Next-Gen Learning Environment (NGLE) Implementation

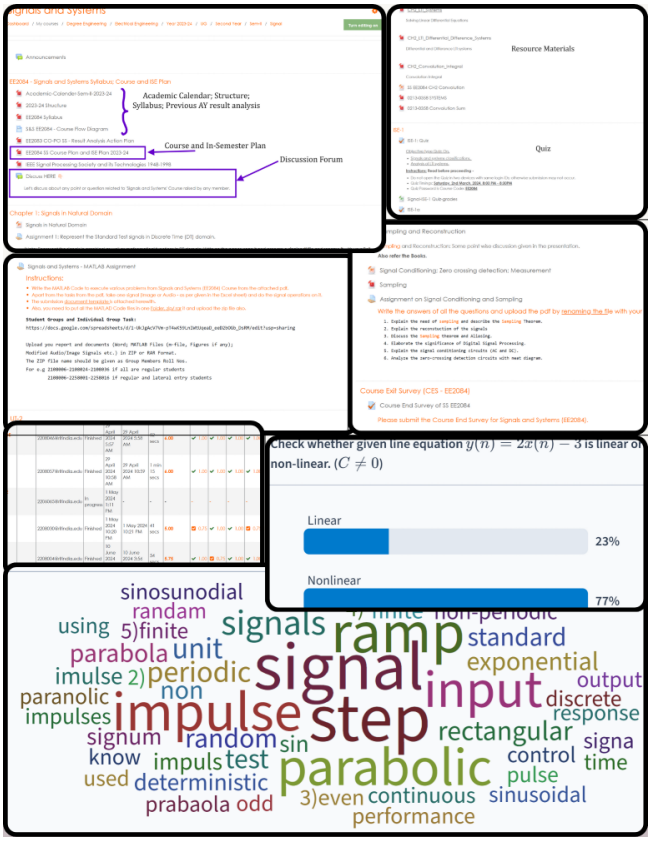


Fig. 3. Activities under NGLE

Institute of Technology Guwahati is used (Virtual Lab 2024). Virtual lab experiments like operations on signals; odd & even components of a signal; Fourier series sequences; sampling theorem experiments and sample reconstruction can be very effectively illustrated and understood by students. One such sample is shown in Fig. 4.

4) Assessment

he NGLE employs a diversified "formative-summative" evaluation method: formative evaluation constitutes 50% of the total and includes classroom performance, unit tests (UT), online tests, assignments, demonstration and comprehensive simulation tasks. The remaining 50% is based on summative evaluation through an end semester examination (ESE). This evaluation method highlights both diversity and scientific rigor, as illustrated in Fig. 5.

Online tests, unit tests, and assignments primarily assess the understanding of fundamental theoretical knowledge and

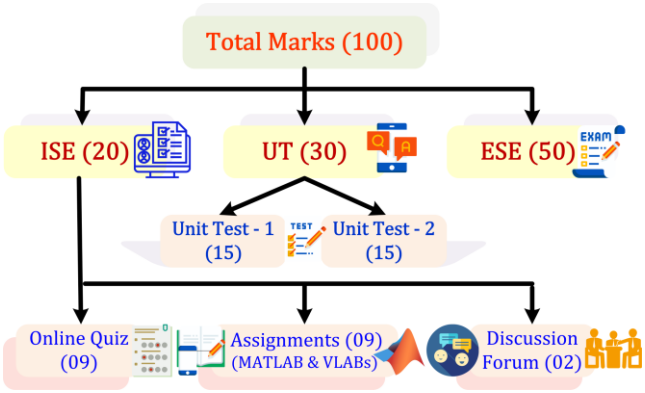


Fig. 5. Evaluation Scheme of SS Course

students can apply the concepts taught in the classroom activities. Classroom activities, such as interactions, presentations, and discussions, evaluate knowledge comprehension, collaboration skills, and summarization abilities. Group tasks like simulations and projects tasks emphasis on the learning by doing and exploration skills. The theoretical written ESE, accounting for 50% of the total score, evaluates proficiency in basic concepts, calculations, and principles.

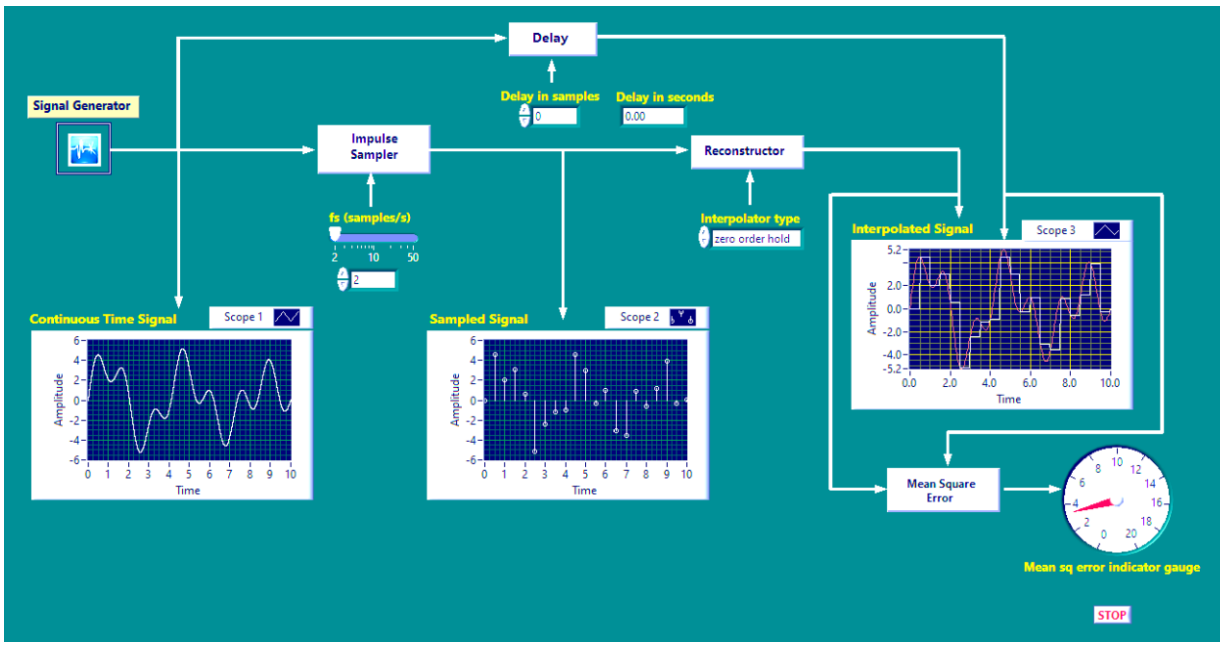


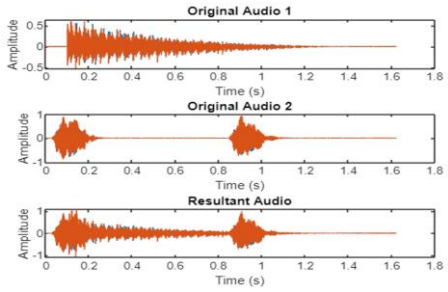
Fig. 4. Virtual Lab Demonstrations of Sample Reconstruction

TABLE I
RUBRICS FOR MATLAB ASSESSMENT

Criteria	Excellent (100-76) %	Good (75-51) %	Average (50-26) %	Unacceptable (25-0) %
Analytical Approach (30%)	Connects MATLAB concepts to data processing and plotting in a creative and accurate way.	Connects data processing and plotting concepts to MATLAB.	Appropriately connects data processing and plotting concepts to MATLAB.	Does not connect MATLAB ideas to data processing
Demonstration (30%)	Exhibits a remarkable degree of analytical reasoning, inventiveness, and ingenuity about the interpretation, assessment, and demonstration of spatial data.	Effectively and creatively illustrates a high degree of critical thinking in the analysis, assessment, and presentation of spatial data.	Exhibits a mediocre degree of critical thinking in terms of correctly interpreting, evaluating, and presenting spatial data.	Exhibits a poor degree of critical thinking in interpreting, evaluating and presenting data.
Presentation and Q&As (40%)	• Clearly and without hesitation responds to enquiries; • Graphs are flawless and blend in perfectly with other materials.	• Clearly responds to questions • Graphs are supported with other material	• Clearly responds to questions • Graphs are plotted	• Responds inaccurately to questions • Incorrect graphs are plotted.

In ISE assessment, there are two major components which directly signifies the NGLE in SS course. The MATLAB assignments are given to students in groups and are assessed based on the defined rubrics as depicted in the Table I. The MATLAB assignment helps students in acquiring the technical software skills and give an opportunity for them in getting better placement. Each group has been given a special task of manipulating audio signal and image signals apart from time dependent signals, and it is found that students done their research and obtained the results in MATLAB, as shown in the Fig. 6.

The Virtual Lab demonstrations support 3 chapters out of 6 chapters of syllabus whereas MATLAB experiments supported



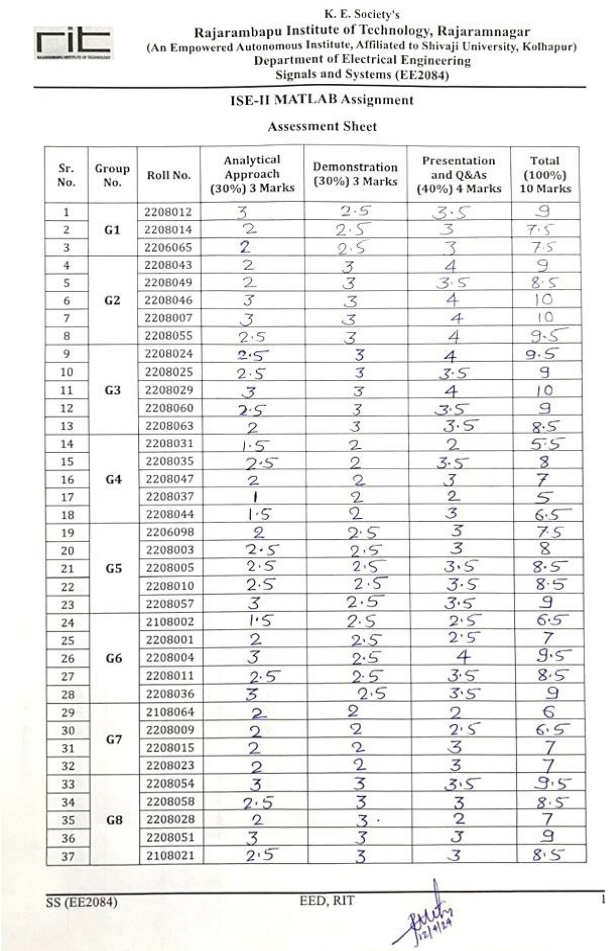
(a)

(b)

Fig. 6. Signal manipulation using MATLAB. (a) Audio signal and (b) Image signal

5 chapters out of 6 chapter of whole syllabus. The assessment of these MATLAB assignment based on the defined rubrics is carried out and each group demonstrated their simulations developed. From each group individual student is assessed from their analytical approach, program or simulations understanding, presentations and question-answer based on the assignment. The assessment is carried out group-wise and each student is evaluated. A sample assessment sheet is illustrated in the Fig. 7.

Furthermore, to assess the effectiveness of NGLE implementation, a Course End Survey (CES) is conducted on



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Department of Electrical Engineering
Signals and Systems (EE2084)

ISE-II MATLAB Assignment

Assessment Sheet

Sr. No.	Group No.	Roll No.	Analytical Approach (30%) 3 Marks	Demonstration (30%) 3 Marks	Presentation and Q&As (40%) 4 Marks	Total (100%) 10 Marks
1	G1	2208012	3	2.5	3.5	9
2		2208014	2	2.5	3	7.5
3		2206065	2	2.5	3	7.5
4	G2	2208043	2	3	4	9
5		2208049	2	3	3.5	8.5
6		2208046	3	3	4	10
7		2208007	3	3	4	10
8		2208055	2.5	3	4	9.5
9	G3	2208024	2.5	3	4	9.5
10		2208025	2.5	3	3.5	9
11		2208029	3	3	4	10
12		2208060	2.5	3	3.5	9
13		2208063	2	3	3.5	8.5
14	G4	2208031	1.5	2	2	5.5
15		2208035	2.5	2	3.5	8
16		2208047	2	2	3	7
17		2208037	1	2	2	5
18		2208044	1.5	2	3	6.5
19	G5	2206098	2	2.5	3	7.5
20		2208003	2.5	2.5	3	8
21		2208005	2.5	2.5	3.5	8.5
22		2208010	2.5	2.5	3.5	8.5
23		2208057	3	2.5	3.5	9
24	G6	2108002	1.5	2.5	2.5	6.5
25		2208001	2	2.5	2.5	7
26		2208004	3	2.5	4	9.5
27		2208011	2.5	2.5	3.5	8.5
28		2208036	3	2.5	3.5	9
29	G7	2108064	2	2	2	6
30		2208009	2	2	2.5	6.5
31		2208015	2	2	3	7
32		2208023	2	2	3	7
33	G8	2208054	3	3	3.5	9.5
34		2208058	2.5	3	3	8.5
35		2208028	2	3	2	7
36		2208051	3	3	3	9
37		2108021	2.5	3	3	8.5

SS (EE2084) EED, RIT 1

Fig. 7. Sample assessment sheets of MATLAB assignment

Moodle, from various perspectives after the course is completed, evaluating the teaching outcomes and the course's acceptability. Also, at conclusion of MATLAB sessions,

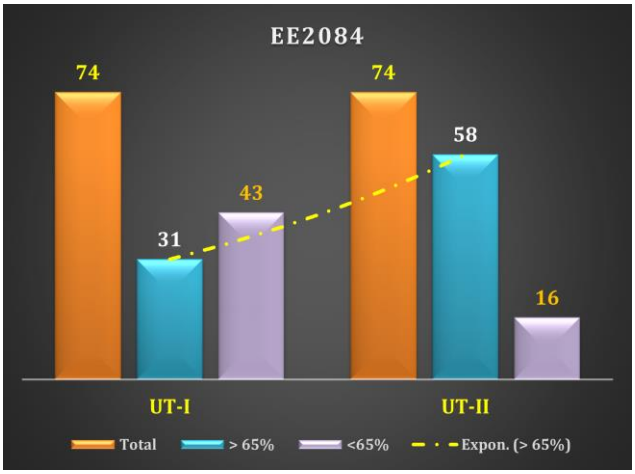

Fig. 8. Unit Tests (UT-1 & UT-2) SS course marks analysis

feedback review was conducted to gather students' opinions on their experience with the MATLAB assignment. The student feedback highlights that the MATLAB sessions significantly enhanced their understanding and practical skills in using MATLAB, particularly for tasks in electrical engineering – SS course and digital signal processing. Many students appreciated the assignments, noting they were beneficial in learning various commands, functions, and the application of MATLAB in solving complex problems. The guidance provided during the sessions helped students overcome challenges, and overall, they found the experience valuable for their future academic and professional endeavors.

Unit Tests are part of continuous teaching-learning and assessment. Although the implementation of NGLE in from the beginning of the semester, students coped-up with this after few weeks and same is reflected in the results of unit test-1 and unit test-2 results. The Figure 8 shows that in UT-1, there are less students who scored 15 or more out of 25 whereas it is improved in UT-2 Furthermore, the overall grading of Signals and Systems course is discussed in the next section.

III. Results and Discussions

To assess the effectiveness of NGLE implementation, an online questionnaire survey is conducted from multiple perspectives after the SS course is completed, evaluating both the teaching impact and the course's acceptability. Out of 74 students in SS course, 71 participated in the survey.

The results of questionnaire survey's statistical analysis indicate that, 87.32% of students expressed that NGLE enhanced the understanding of SS course effectively. Furthermore, 97.18% of students highly favored the blended teaching approach, and found interactive sessions are very significant. Additionally, same percentage students feel that learning resources provided are proper and easily accessible. However, 12.68% students disagreed or kept neutral view on assessments carried out. These results are shown in the Fig. 9. More than 95% students found the NGLE teaching learning contributed in developing the critical thinking and problem-solving skills and similar response is obtained which says

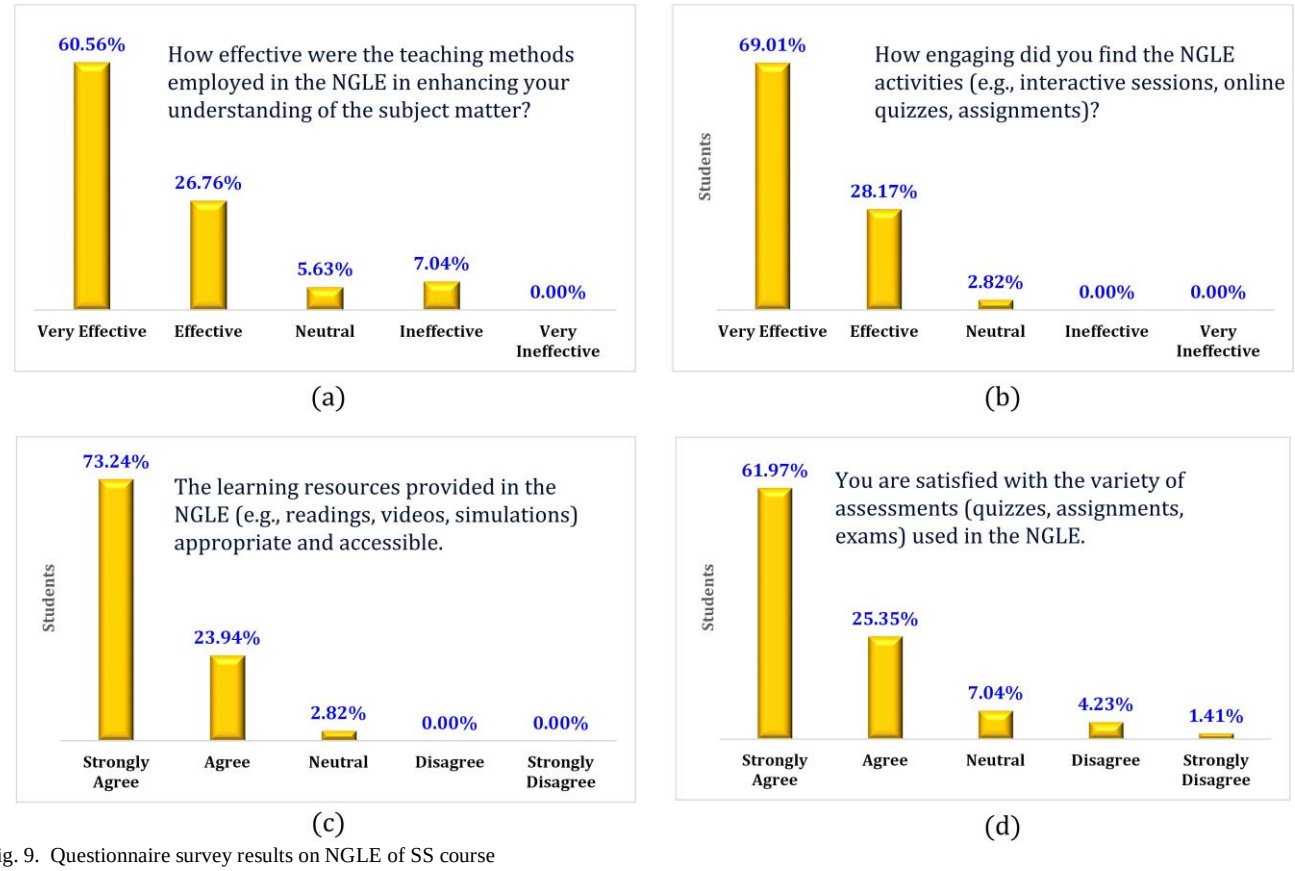

Fig. 9. Questionnaire survey results on NGLE of SS course

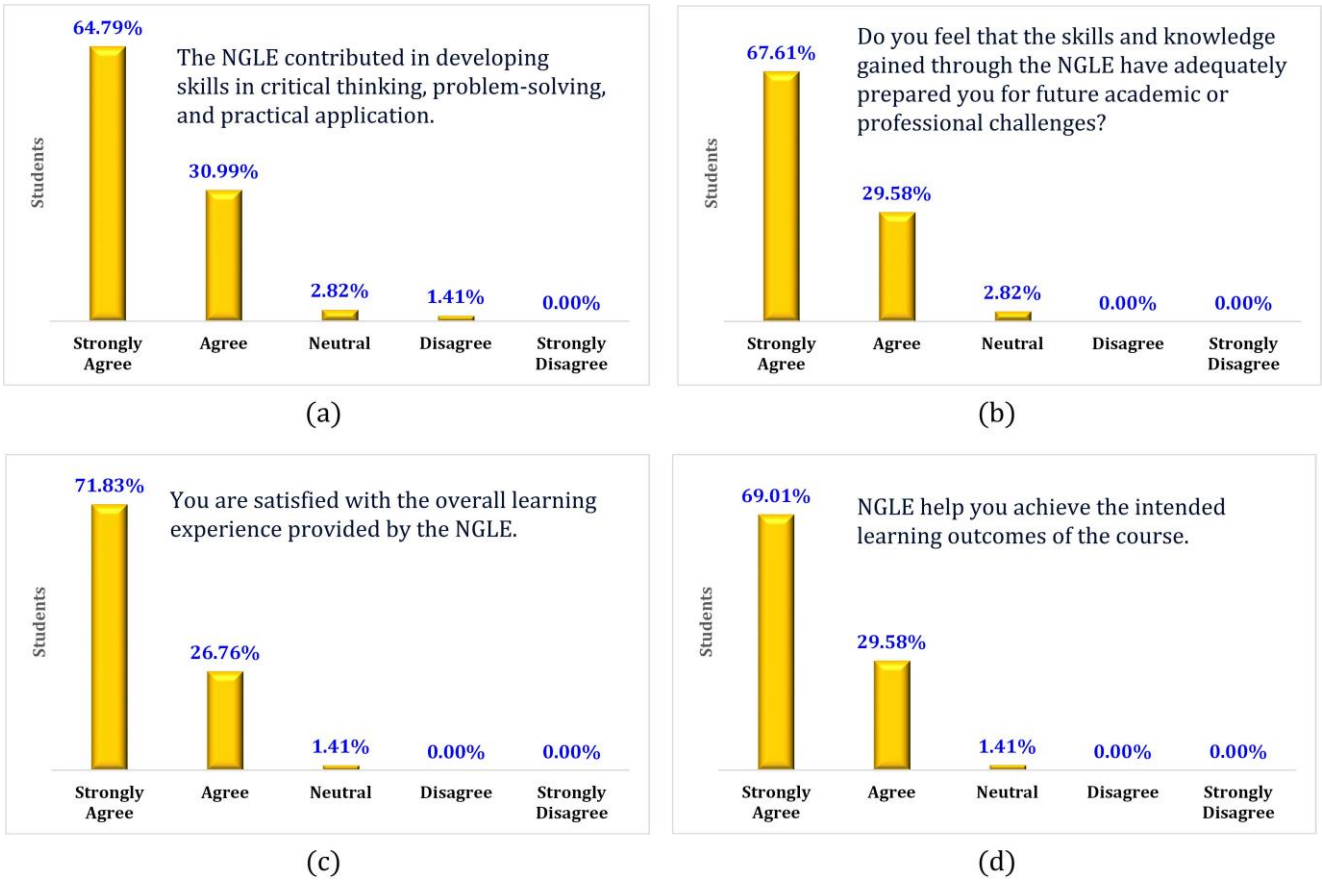

Fig. 10. Questionnaire survey results on overall NGLE implementation of SS course

NGLE was helpful in future endeavors. Overall experience of NGLE in SS course illustrated that more than 97% students satisfied with this activity and help to achieve the course outcomes. These results are depicted in the Fig. 10.

The final grades for SS course after ESE are given in the Fig. 11, showed improvement in higher grade percentile compared to previous year. Previous year there were less than 4% and 5% students achieved the AA and AB grades, which improved with integration of NGLE. These grades equivalent values on the scale of 10 is presented in the Table II. Furthermore, the comparison of course outcome (refer Table A in Appendix for course outcome statements) attainment is carried out for the current batch (2023-24) and previous batch (2022-23). The attainment of both the batches is illustrated in Fig. 12. The comparison shows that there is improvement in the attainment of CO1, CO3 and CO4, whereas CO2 and CO5 maintained the attainments. The attainments are calculated keeping threshold value of 60% and 65% for 2022-23 and 2023-24 batches respectively.

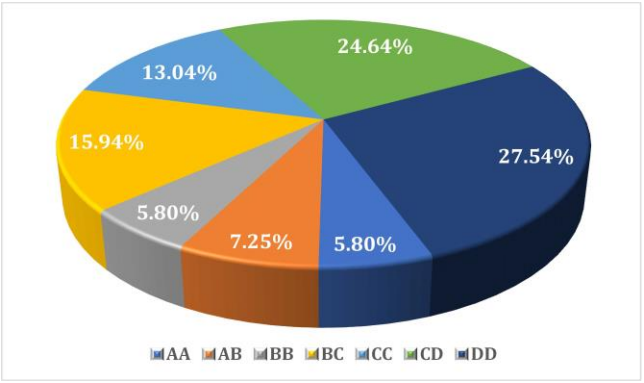

Fig. 11. Grades after ESE of SS Course

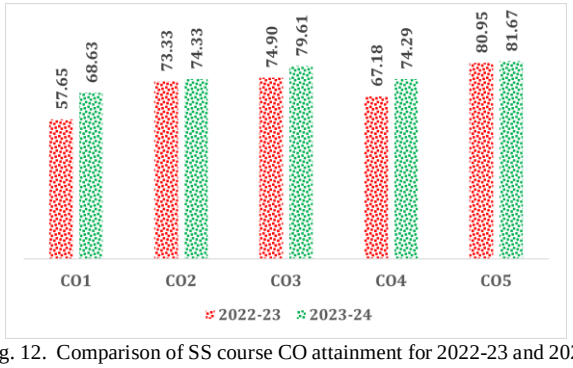

Fig. 12. Comparison of SS course CO attainment for 2022-23 and 2023-24 batches

TABLE II
GRADES EQUIVALENT VALUES ON SCALE OF 10

Grade	AA	AB	BB	BC	CC	CD	DD
Scale of 10	10	9	8	7	6	5	4

However, still there is a scope for improvement in upgrading students' grades specially from CD and DD grades to higher grades. Therefore, based on the observed grade improvements and the feedback collected, NGLE leaves a substantial positive impact on enhancing academic performance of undergraduates.

These findings propose that the NGLE is an impactful tool in modern engineering education, offering a comprehensive platform for students to excel in both theoretical and practical skills of Signals and Systems course.

CONCLUSION

The proposed research of integrating Next-Gen Learning Environment has significant implications for engineering education. By demonstrating the effectiveness of NGLE in teaching complex subjects like Signals and Systems, this study provides valuable insights for educators aiming to boost the excellence of engineering education. Furthermore, it has proven to be highly effective in enhancing student engagement, understanding, and academic performance. The statistical analysis of feedback survey results and grade improvements and course outcome attainment indicate that the NGLE not only supports diverse learning styles but also nurtures a deeper comprehension of complex concepts through interactive and practical learning experiences. The positive feedback from students further validates the success of this approach, highlighting the value of blended teaching methods and advanced simulation tools in strengthening foundational knowledge and practical skills.

Furthermore, the findings could serve as a reference for implementing NGLE in other technical disciplines, thereby contributing to the broader goal of advancing educational practices in the digital age.

APPENDIX A

Course outcomes (CO) of Signals and System (SS) course.

TABLE A
COURSE OUTCOMES OF SS COURSE

	Course Outcomes (CO)
CO1	Perform mathematical operations on signals.
CO2	Discuss various system properties.
CO3	Discuss need of frequency domain analysis and its properties.
CO4	Compute the Fourier series or Fourier transform of a set of well-defined signals from first principles.
CO5	Apply Z and Laplace transforms.

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