# Experiential Learning Framework for Signals and Systems: An Attempt Towards Reaching Higher Levels of Cognition.

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**Abstract:** In this paper, we propose an experiential learning module for the course Signals and Systems (SNS). This course is designed in the second year of the Electronics and Communication Engineering stream and challenging course as it demands a higher level of cognition skills. Experiential learning is a series of activities that allow students to be actively involved in ensuring learning. The experiential learning module enhances the problem-solving skills towards reaching higher levels of cognition, moving from the lower levels of remembering, understanding. Typically, the conventional modes are teacher-centric, visual learners and sequential learners find challenges in stimulating their cognition skills. Towards this, we design an experiential learning framework with two techniques: Concept inventory and SNS with Python to facilitate sequential learners and visual learners respectively. The challenges associated with the deployment of our framework are time and resource management. The proposed framework facilitates achieving a higher level of cognitive skills; also the introduction of the simulating tool ensures the conceptual learning of the course beyond classroom learning.

**Keywords**: Cognition skills, Concept inventory, Python, Sequential learners, Visual learners

## 1. Introduction

Facilitation of the course content using traditional methods i.e. chalk and talk method initiate only knowledge transfer of 100% for the creamy layer of students. The statistics reveal that 65% of the students are visual learners and the rest are sequential learners. It is the responsibility of a tutor to discover and implement different pedagogy methods to be inculcated with traditional teaching [1], [4]. Signals and Systems is one of the basic courses in the Electronics and Communication curriculum and the concepts in this course are closely associated with mathematics. This course is a prerequisite course for different core courses like DSP, Communication, VLSI, Wireless communication, etc. As a mathematically oriented subject, students found it challenging to link mathematics and Signals and Systems course concepts to solve given signal processing applications due to a lack of a higher level of cognition skills and visualization of the concepts. To improve their cognition skills Concept inventories were floated to build the competency among the learners to address problems of the course Signals and Systems. Typically, the problems are designed at different levels of Bloom's taxonomy, and students are allowed to carry out this activity as a part of their continuous evaluation [2], [3]. The performance at different complexity levels is used to retune the structure of the further synchronous sessions. To enhance their visualization skills of signals and systems concepts a programming language called Python was introduced. This approach develops a constructive framework in students' minds to represent the concepts behind mathematics logically. This approach provides the benefits of visualization of signals and its operations to the learners along with enhancing their coding skills. We consider the employer's feedback and choose Python as a supporting language for the course Signals and Systems. Implementation assignments including signal generation and its operations are designed and evaluated as part of their continuous evaluation. Experiential learning is appreciated by experts and also by students. Authors in [10], [11] discuss "Learning by doing" activity to ensure the learning beyond the classroom teaching.

For many years KLE Technological University has placed prior emphasis on achieving almost all the educational outcomes demonstrated by the OBE framework. The activities introduced in the signals and systems course play a very significant role in programmatic accreditation and better assessment of learning outcomes for continual improvement. Major efforts as a facilitator are to provide a better assessment tool for enhancing the learning capability of the pupil as well as to extend the learning outcome assessment. To improve the overall assessment strategy of the course signals and systems an additional pedagogy method is introduced in this paper.

The content that is being covered fairly distributes from introducing the concept of signals, systems, and their analysis for continuous-time and discrete-time signals, its interaction with continuous-time and discrete-time systems, and related properties. Also, the students experience frequency domain existence for every time-domain representation that provides a lower level of abstraction in the form of trigonometric and exponential Fourier series, Fourier transforms, Z transforms and their applications. All these concepts are pretty challenging for a facilitator to convince the students because the course is more bent towards the conceptual analysis, contains a higher level of abstraction and a student needs to have a strong fundamental base in mathematical solving skills as well as comprehension of the meaning behind the mathematics as the students are being exposed to the frequency domain as well [7], [8]. A necessity to create a contemporary method of teaching signals and systems was undertaken with the following objectives [5].

1. Discussion space to be provided in the course curriculum which avoided the exact material sharing of the concepts explicitly.
2. As a part of self-learning assessment, the introduction of computer tools for demonstrating different concepts of signals and systems is initiated.
3. To create a platform where students were challenged to represent their understanding of concepts.
4. To design inventory sessions that described the exact platform for evaluation of program outcomes.

Further, the paper presents the variation in pedagogy method implementation details, its implementation, its outcomes, and its reflections through continuous monitoring, feedback, and in semester end exam.

## 2. Methodology

In this section, a detail of the pedagogy method is discussed. An operative framework that will initiate the learning of signals and systems course more effectively will be to

- Comprehend and learn the basics
- Inculcate the challenges involved in solving real-time projects.
- Visualization of information and its processing.
- Applying these concepts to earn other connected engineering courses as well.

The proposed framework discusses the methodology adopted in course delivery which initially involves rigorous brainstorming sessions that identified the difficulties of students at a different level of the course delivery. The analysis was obtained by looking at the performance of the students in the previous consecutive years for both in-semester and end-semester assessment. A typical pattern of mistakes committed was observed at various levels starting from application of exact theorem/formulae to solve a given problem, visualization of signal representation and its analysis, and lastly the application of frequency-domain analysis on different signal classes [12].

## 3. Implementation

To address the challenges discussed in the above section, the new pedagogical practice adopted in the signals and systems course is discussed in the implementation part that focuses on the improvement of the cognitive and visualization skills of the students. Two methods attempted by the author of introducing the concept inventory and python programming language are discussed in detail in this section.

### A. Concept Inventory

Concept inventory is a new pedagogical practice adopted to enhance the cognition skills of the students. Concept inventory is created for each chapter in the course which includes questions at a different level of complexity

- Let's Revise It: Objective type of questions.
- Let's Crack It: 2 Mark questions.
- Let's Drill It: 5 Mark questions.

The inventories were floated to students as a pre-test before their in-semester assessment after the completion of each unit in the course [6]. The sample of the question asked in the inventory at a different level of Bloom's Taxonomy.

**Activity: Unit-I Inventory**

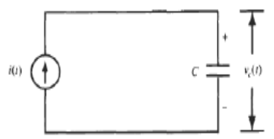
| | |
|---|---|
| | **Let us Revise it** |
| 1 | For a periodic signal $v(t)$=30sin100$t$+10cos300$t$+6sin(500$t$+π4), the fundamental frequency in rad/s is<br>(a) 100 (b) 300 (c) 500 (d) 1500 |
| 2 | If a signal f(t) has energy E, the energy of the signal f(2t) is equal to<br>a) E b) E/2 c) 2E d) 4E |
| | **Let us crack it** |
| 1 | A continuous-time signal is given as x(t)=2{u(t+2)-u(t-1)}. Sketch and label each of the following signals.<br>(a) x(t - 2); (b) x(2t); (c) x(t/2); (d) x(-t) |
| 2 | Draw the direct form I and II block diagram representation for the following difference equation of a system.<br>$y(n)+\frac{1}{2}y(n-1)-\frac{1}{3}y(n-3)=x(n)+2x(n-2)$ |
| | **Let us Drill it** |
| 1 | Consider the capacitor shown in Fig. 1-33. Let input x(t) = i(t) and output y(t) = $v_c$(t).<br>(a) Find the input-output relationship.<br>(b) Determine whether the system is (i) memory less, (ii) causal, ( iii ) linear, iv) time invariant, v) stable.<br> |

Fig. 1 Concept inventory example

Fig. 1.depicts the sample question paper of the concept inventory being designed for the students to attempt. It clearly shows that the students were exposed to different levels of questions from the remembering level to the applying level. This pedagogy approach helped the students to improve their cognition skills. This type of evaluation was performed twice during the semester. The first concept inventory was introduced before In-Semester-Assessment 1 and the second one before In-Semester-Assessment 2. This practice benefitted students in multiple ways ranging from enhancing their problem-solving capabilities to helping them in thorough preparation for the exams they appear in. This approach initiated a lot of interactive sessions that focused on doubt clearing sessions after the students attempted the concept inventory which otherwise in normal methodology is not seen that often by large strength [13].

### B. Visual Learning

To enhance the visual learning of the student's particular signals and systems course, a programming language called Python was introduced. This approach effectively creates an environment of computer algebra which promotes a mixed environment of computer and mathematics skills. The introduction of programming language to solve mathematical oriented concept allows the learners to better understand the topics by arriving at a method to implement the concept logically, plotting the results, and creating inferences of the data obtained. As the students are familiar with C programming and are also exposed to the environment of MATLAB in their previous semester, introducing Python language became a feasible solution to provide better learning of the course to the students. The activity was introduced at the beginning of the course. The entire course is evaluated for 4 credits of the complete UG credit system of the 3rd semester. All the courses in the university are divided concerning the way the course is been taught to the students. The standard form is Lectures-Tutorials-Practical's and also sometimes introduction of self-study component to the course i.e. is L-T-P-SS. Signals and systems course with the new pedagogy method was distributed in the following fashion 3-0-1-0. That is 3 credits for the lectures which include the assessment In semester (ISA), End semester (ESA), and Concept inventory. 1 credit was purely introduced as a practical session for solving the concepts of signals and systems using Python programming language making use of Spider tool. This task was conducted in two phases

Phase 1: Learning the programming tool.

To make students familiar with the programming language individual Hacker Rank accounts for all the students were created and the students solved all the problems with varying complexity. It benefitted the students to build their logical competency and also get fair recognition in the Hacker Rank race which is observed by different reputed companies that come to the campus for placements. Fig. 2 and Fig. 3 show the screenshot of one example of a student registered for hacker rank and scoring ranks for solving the problems.

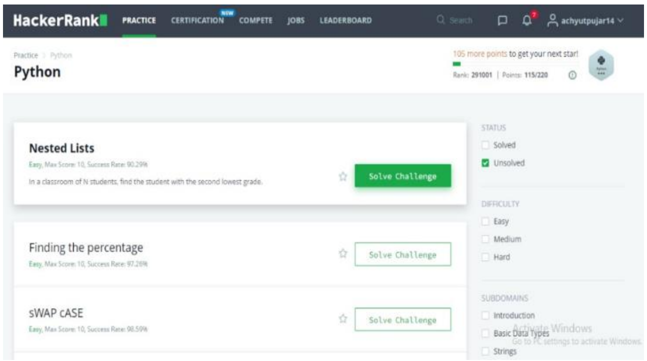



Fig. 2 Hacker rank registration of a student to learn the programming language

Students were benefitted to a very large extent as they were able to solve the present world problems floated in the forum and provide their unique solutions [9].

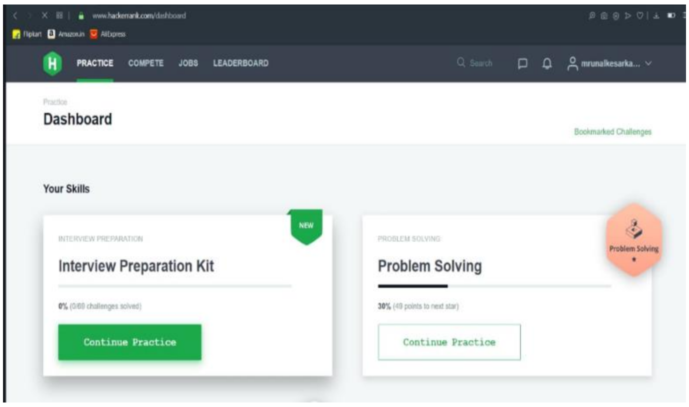



Fig. 3 Hacker rank registration of a student to learn the programming language

Phase 2: Implementation of signals and systems concepts using Python language

Different concepts of signals and systems problem statements were formulated and floated to students which they initially build logic using Python language and later observe and analyse the results. Table 1 reflects the various topics that were covered for Python implementation.

**Table 1. Concept illustration for Python implementation**

| S. No | Concepts |
|---|---|
| 1. | Generation of Complex real-world signals using elementary signals. |
| 2. | Performing various basic operations on signals on both dependent and independent variables. |
| 3. | Analyzing the response of a system using impulse response representation of the system-Convolution Process. |
| 4. | Performing test cases for checking the different properties of the system. |
| 5. | Frequency domain analysis using Discrete-time Fourier series, Discrete-time Fourier transform tools and Z transforms. |

Sample problems solved by the students have been depicted in Fig. 4, 5, and 6 which showcases the way students have developed a logic for solving different problems.

WRITE A PYTHON PROGRAM TO ADD TWO SINUSOIDAL SIGNALS OF FREQUENCY 1K HZ AND 10K HZ, AND PLOT ALL THE THREE SIGNALS IN ONE FIGURE USING SUBPLOT COMMAND.

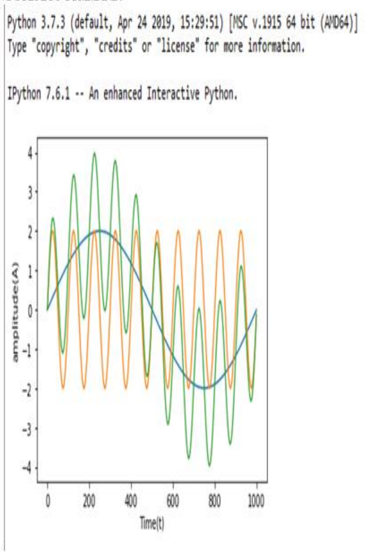



Fig. 4 Python program for the generation of complex signals using elementary signals

CONSIDER A SIGNAL $x(t) = -2 * tri\left(\frac{t-1}{2}\right)$. WRITE A PYTHON PROGRAM TO PLOT THE FOLLOWING SIGNALS IN A SINGLE FIGURE WINDOW.

- X(T), X(2T - 1), X(-T + 6), X(-3(1 - T)), X(T – 0.5), X(T/2 + 1))

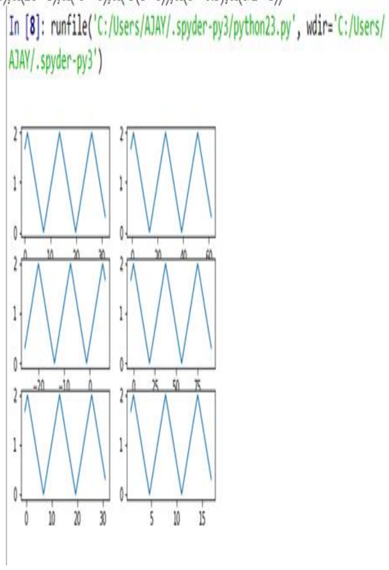



Fig. 5 Python program for performing basic operations on the independent variable of a signal

THE IMPULSE RESPONSE OF A LINEAR TIME INVARIANT SIGNAL IS GIVEN BY ITS OUTPUT (RESPONSE) AS A RESULT OF APPLYING IMPULSE AS INPUT. WRITE A PYTHON PROGRAM TO FIND THE RESPONSE OF AN LTI SYSTEM DESCRIBED BY THE IMPULSE RESPONSE H(N) = (0, 0.25, 0.5, 1, 0.5, 0.25, 0) WHEN THE SYSTEM IS EXCITED WITH A UNIT RECTANGULAR SEQUENCE OF WIDTH 7 (SYMMETRIC SEQUENCE). PLOT ALL THE SIGNALS IN A SINGLE FIGURE WINDOW USING SUBPLOT COMMAND.

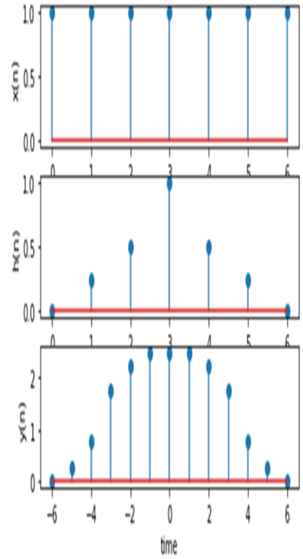



Fig. 6: Python program for performing convolution process to obtain the system response

The problem statements given were implemented in python and were also validated theoretically with a pen and paper approach. Fig. 7 shows the theoretical solution of one of the problems on convolution whose results match with the implementation results shown in Fig. 6.

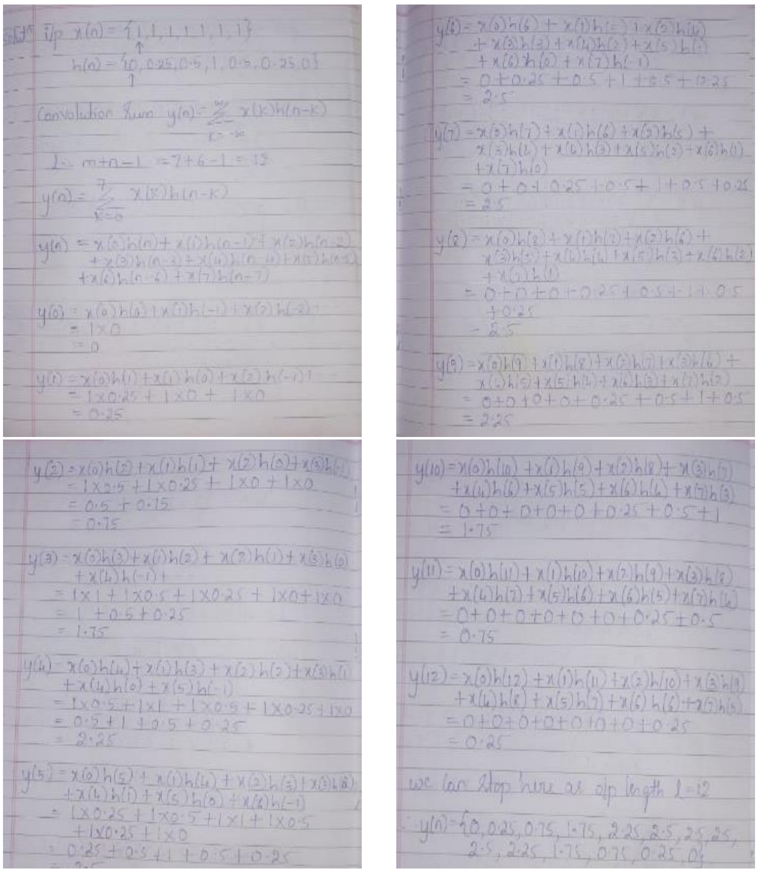


Fig. 7: Theoretical verification of convolution sum for the implemented problem

## 4. Results and Discussions

The effectiveness of the activity is measured in terms of an increase in the percentage of bloom taxonomy level questions asked during the students' assessment through ISA and ESA evaluations and also addressing the program outcomes. Earlier this course was mapped to only two program outcomes related to Engineering knowledge and problem-solving skills [14]. After the introduction of the proposed pedagogical practice, the activities were mapped to the program outcomes which helped to assess the students' performance effectively thereby addressing the other program outcome related to proficiency in using the EDA tool. Fig. 7. and Fig. 8. shows that the L2 and L3 are almost 50% but after the introduction of the proposed pedagogy method, we can see that there is an increase in the L3 level questions in both ISA and ESA on an average of 40%.

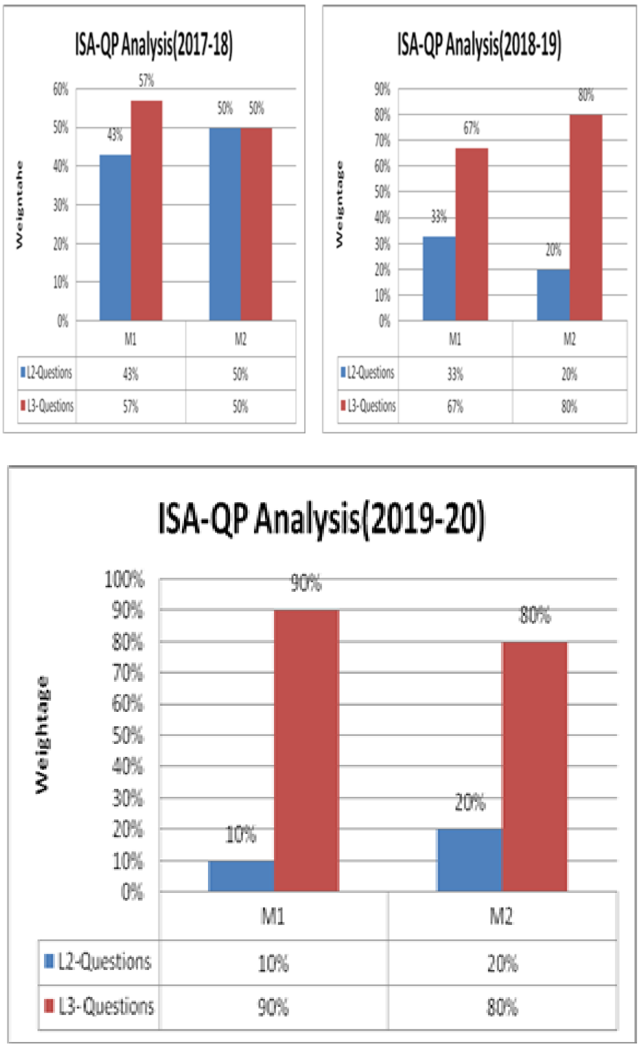



Fig. 8 Blooms Taxonomy Level Analysis in ISA Evaluation for three consecutive years

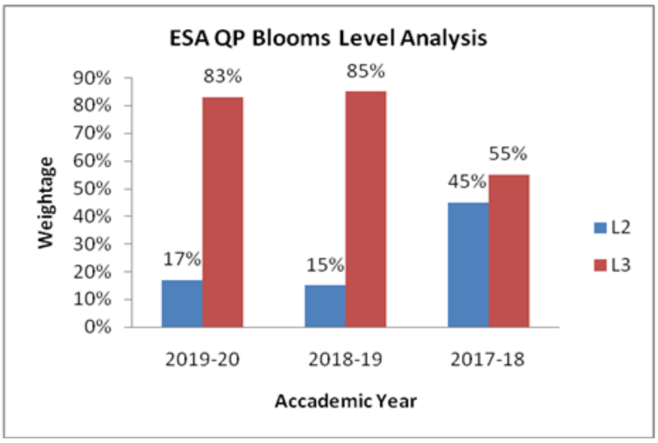



Fig. 9 Blooms Taxonomy Level Analysis in ESA Evaluation for three consecutive years

The effectiveness was also measured in terms of students' feedback collected after the completion of the activity. The feedback questions were on the development of their cognitive skills, coding skills, visualization of concepts, attempting, and representing the questions of the higher level of Bloom's taxonomy. Fig. 9 shows the response of the students which depicts that the majority of the students gave positive feedback and expressed that the pedagogical practice helped them in improving their problem-solving skills; it also helped them in visualization and a better understanding of concepts. The students also expressed that the coding platform introduced helped them in improving their coding skills in this course and also will be beneficial in the courses learned in the higher semesters [15].

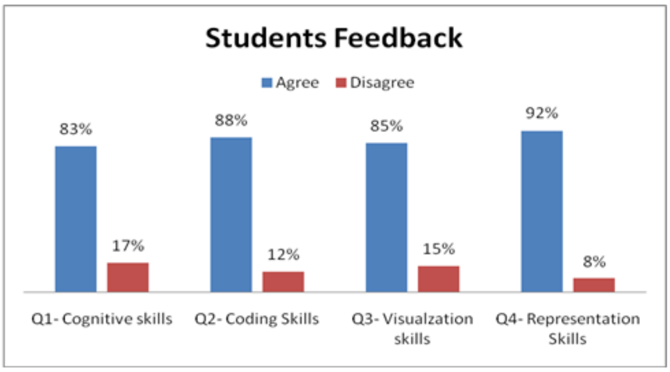



Fig. 10 Students Feedback

## 5. Conclusion

In this paper broadly we discuss the challenges faced by the facilitator to teach the course and address a large classroom, also the problems faced by the students in the analysis as well as the application of various concepts to solve real-world problems. The paper details the implementation of concept inventory which created a constructive environment in the improvement of the cognitive skills of students an introduction to modern engineering tools and programming language for performing different concepts of the course which build a better visualization capability in approaching a problem and also solving it. A framework was developed to assess the program outcomes which in turn keep the track of student achievement. This pedagogy method indeed created an environment where the amount of work expected by the students has significantly increased. Despite this reason, the overall student ratio expressed a positive attitude with which we were able to achieve better results and assess the program outcomes effectively. The study reveals that there is a significant improvement in PO mapping and its attainment in the broad areas of communicating effectively, critical reflection of problem-solving skills, ability to learn new tools, and programming language. The pedagogy discussed in the paper provides experiential learning facilities in achieving a higher level of cognitive skills. The add-on programming and simulation tool along with problem-solving ensures the conceptual learning of the course beyond classroom learning.

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