The EET Communication Simulator

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Abstract

There is a fundamental challenge in teaching communication systems to electrical engineering technology (EET) students, that is, how do you convey the various abstract concepts in a way that students fully appreciate, without the mathematical rigor of the standard engineering approach? To answer this question, a class project was assigned to groups of students in the Telecommunication Fundamentals course. The purpose of the project was two-fold: (i) to develop a software communication simulator that an instructor can use to teach his/her students various communication concepts in a visual way, and ii) it must be such that a student can use it at his/her own pace to learn communications concepts. Several groups of students worked to improve the simulator over a period of two years while all others in the classes participated in the user focus group. The user focus group gave their input through the completion of surveys, upon using and evaluating the simulator.

In this paper, a complete discussion of the implementation of the projects, survey results and the findings of this study are presented. Additionally, future improvements are recommended.

Introduction

There are several ways to teach a fundamentals of Telecommunications course. In a standard electrical engineering program, emphasis is placed on mathematical models. This approach assumes a certain level of mathematical competency among the students. MATLAB may be used to make it more appealing through visual representations of communication signals such as amplitude modulated (AM) or pulse code modulated (PCM) signals. Simulink may also be used to model a complete communication system with several building blocks. Nonetheless, sometimes students struggle to understand some of the abstract concepts. Especially, if they are presented in a strictly lecture format with an emphasis on the mathematical representation of the communication and signal processing functions.   This is especially true in the electrical engineering technology classroom where the emphasis is more on a 'hands on' approach with less mathematical rigor. In such a setting as this, the question was asked, "how can students be engaged in the classroom in a way that enhances their learning of telecommunications fundamentals? " A novel approach was presented as a response to the preceding question. The idea was to allow the students to design an educational simulator for themselves that facilitate the following learning paths: (i) an instructor-led tool that could visually demonstrate the various mathematical models introduced in the classroom and ii) a student-centered tool that one could use at his/her own pace to reinforce or learn the theoretical concepts presented in the classroom.

The fundamental premise and guiding principle was that the students should be able to learn through visual representation of the complex mathematical equations that model various stages of signal processing in telecommunication systems.   Simply put- if students are able to see the waveforms that are represented by the equations (and algorithms), are able to interact with the models by changing various parameters and instantly seeing the corresponding system change,

then they may appreciate the underlying mathematics and learn the concepts easier and better. Also, allowing the students to design the tool for the instructor encourages them to determine what aspect of the course they had difficulty learning, and how they believed this could be remedied.

Common Software Tools used in Introductory Telecommunications Systems Courses

In this section, some of the most popular software tools that are used in telecommunication courses are presented. Afterwards, a case is made as to why it was necessary to develop a customized telecommunications simulator. Telecommunication is a vast discipline. However, in an introductory to telecommunications course the curriculum normally includes 3 main aspects (sub-areas): signal processing, signal transmission, and introductory data communication. The popular tool for the corresponding sub-area are listed below.

1. Signal processing-MATLAB & SIMULINK[1]
2. Signal transmission-Microwave Office[2]
3. Data communication- Riverbed Modeler[3] (formerly OPNET modeler)

MATLAB is a high level programming language for technical computation. The software includes computation, viewing, and programming in a user-friendly environment. Although MATLAB has a user-friendly graphical user interface (GUI) interface, its functions are primarily executed through commands. Therefore, the user must know these commands and the syntax of the programming language. Common uses of MATLAB include: a) plotting of complex mathematical equations, b) mathematical computations, c) algorithm development, and d) modeling and simulation.

SIMULINK has an interactive environment that facilitates the modeling and simulation of dynamic systems. The software allows the user to build entire systems by using standard built-in blocks or customized blocks (sub-system). The simulation can be performed from the menus or from the command line. System's performance can be observed during the simulation or recorded to a file. Additionally, the results can be exported to MATLAB for a more comprehensive analysis or processing. SIMULINK is supported by MATLAB and its group of toolboxes that offers a comprehensive set of tools for engineering and mathematics, to define algorithms, analyze data, and display results. Together, MATLAB and SIMULINK provide powerful integrated environment for simulation, modeling, and prototyping.

A popular microwave software environment, in both academia and industry, is AWR Microwave Office (MWO) from National Instruments. MWO is the linear and nonlinear solution for microwave hybrid, module and monolithic microwave integrated circuit (MMIC) design. Features include linear, harmonic-balance, time-domain, electromagnetic simulation, physical layout, and linear and nonlinear noise analysis. In general, MWO is a frequency domain simulator.

MWO can generate a layout view from the schematic diagram. Also, MWO includes a transmission-line calculator, TXLINE, that can analyze or synthesize various lines, such as

microstrip, stripline or coaxial. MWO has many powerful features and is not usually suited for an introductory course.

Riverbed Modeler (formerly OPNET Modeler) offers a virtual environment for computer communication (networking). The software has an extensive library with network devices that model real systems. These models include routers, switches, data links, hubs, workstations, servers, and protocols. Riverbed modeler is a powerful and comprehensive software tool that allows researchers and product development teams to implement and test prototype protocols and network devices. However, its very user-friendly graphical user interface (GUI) and simplicity of operation allow it to be a suitable software tool in an introductory course, to help students to understand network protocols implementation and computer networking principles.

In addition to the aforementioned software tools, other commercial products are available such as National Instruments' Visual System Simulator™ (VSS) software. "VSS is an RF and wireless communications and radar systems design solution, supporting realistic measurements of cascaded RF blocks, identifying the source of spurious products and simulating system metrics such as bit error rates all from a single system diagram. Designers of commercial and military transmitters and receivers are then able to quickly and easily create subsystem architectures and optimize their components for best overall performance." [4]

Non-Commercial Simulators Developed by Educators for STEM Curriculum

This section highlights various simulators that are used as a teaching tool for teaching engineering related courses.

A Sosim simulator presented by Maia and Pacheco[5] was used for teaching techniques on modern operating systems. One of the main problems faced within teaching Computer Science courses is the difficulties students face understanding these programming languages to sufficiently write a program that works and gives correct results. This program was used to help students understand programming language concepts. The Sosim simulator contains graphical illustrations to serve as a dynamic support tool for teaching modern operating system concept courses by using a simple visual graphical user interface (GUI) in which the students can learn by visually understanding its concepts and are able to implement their own simulation.

Xiaomei[6] developed a new wireless teaching and learning system (WNTLS) network simulator to help in facilitating the student learning process on various types of wireless networks within the telecommunication curriculum. The WNTLS simulator uses a GUI to assist with the simulation process and for displaying its results. This simulator allows students to understand the material within the telecommunication wireless network curriculum, which are at times hard to understand especially with its complex mathematical and programming-based background. It also improves communication between teachers and students or between students themselves by offering debates on the topic.

Kavianpour[7] discusses the use of LabVIEW for teaching several engineering courses in signal processing, digital circuits, microprocessors, communications, and programming language. These teaching tools were implemented to help students learn the different fundamental concepts

between computer hardware and software programming. The author further discusses several examples with the aid of LabVIEW in teaching these engineering courses which resulted in an increase in academic performance when LabVIEW was being taught within the classroom.

Authors Andreatos and Zagorianos[8] present a MATLAB GUI application for teaching automatic control systems to third year students of the Hellenic Air Force Academy. The course covers topics on input-output and state space analysis of single –output control system, quantitative and qualitative analysis of MIMO control systems, the Root-Locus and frequency domain control design techniques, optimal control, and adaptive control. This tool allows the student to experiment with different sets of parameters to improve their learning of a typical control systems of an aircraft. Venkatalakshmi *et al.*[9] also discusses the use of MATLAB and Advanced Design System (ADS) as a teaching tool for teaching the Fourier transform algorithm for communication engineering students. However, none of these specifically addressed an introductory course in Telecommunication. Furthermore, they did not address our specific needs nor design objectives.

Project Approach

The software was developed over a period of two years with two distinct year groups and three distinct project groups. In the first year, two class project teams, each with three students, were selected. The instructions given were to design a simulator that the instructor could use in his lecture to assist in making the abstract concepts, such as modulation, easier to understand. Also, students should be able to use it at their own pace to better understand the theoretical concepts through the use of visual representations of complex signal waveform.

After 7 weeks, the students presented their initial ideas with graphical user interface (GUI) layout. At this point it was not required for all the functions to be working. One group used LABVIEW to create their simulator while the other group used MATLAB graphical user interface (GUI). Each group demonstrated their simulator in about 15 minutes, including question and answers. Immediately after the demonstration, the audience (entire class) was allowed to complete a survey online, while still in the classroom. This was done to ensure that the best ideas and comments were captured as soon as possible and encouraged full participation of the class.

The idea of the first survey was to allow the entire class to participate as consultants to the project. The good initial recommendations were incorporated into the project. The main critiques were about layout, functionality, and user-friendliness. The same survey was repeated at the end of the semester to the entire class. This was done immediately after the project teams' final demonstration of their working simulator. Doing the same survey twice allowed the developers to see the evolution of their design and provided important comparative data.

In year 2, a third group was selected to continue working on the project. This project group was shown the two previous simulators and the main critiques and recommendations from the final survey. The group was tasked to incorporate the recommendations and critiques that the group members thought were useful to enhance the simulator. They were given the flexibility of using any software development platform. They decided to use JavaScript, since one of the main

critiques of both simulators was that users would require the respective software (MATLAB or LABVIEW) to be installed on their computers in order to use the simulator. Using JavaScript, anyone with the program files and a web browser on his/her computer can use the simulator. At the end of the semester, the entire class was surveyed after the demonstration of the new simulator. The same survey questions and instrument were utilized as in the previous year.

EET Communication Simulator- Design and Operation

The simulator was designed such that instructor or students could see visual representations of mathematical equations. This allowed the students to understand the various steps in analog and digital modulation techniques, including the ability to see how various parameters such as carrier signal frequency impact the modulated signal. Figures 1 to 4 show snapshots of the simulator in action.
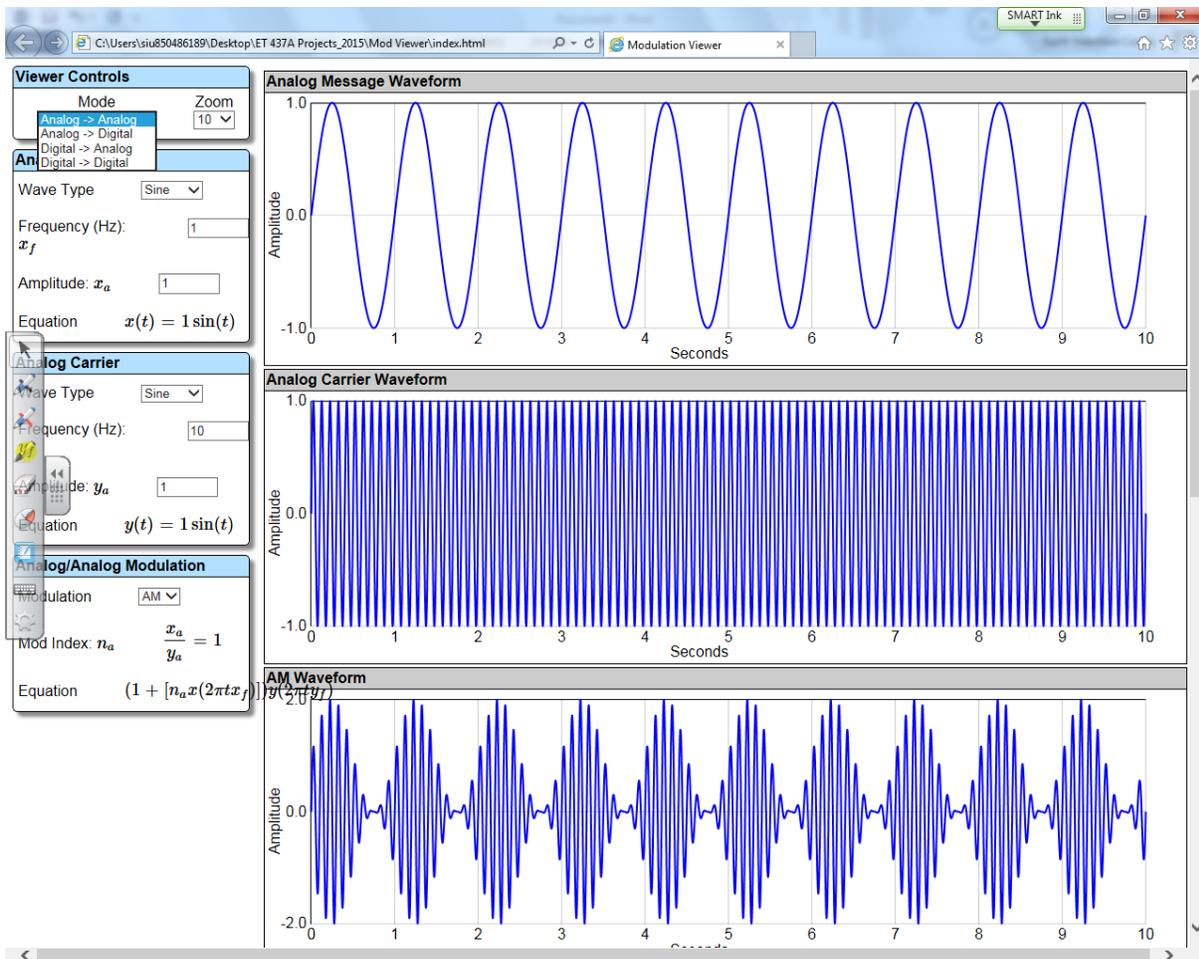

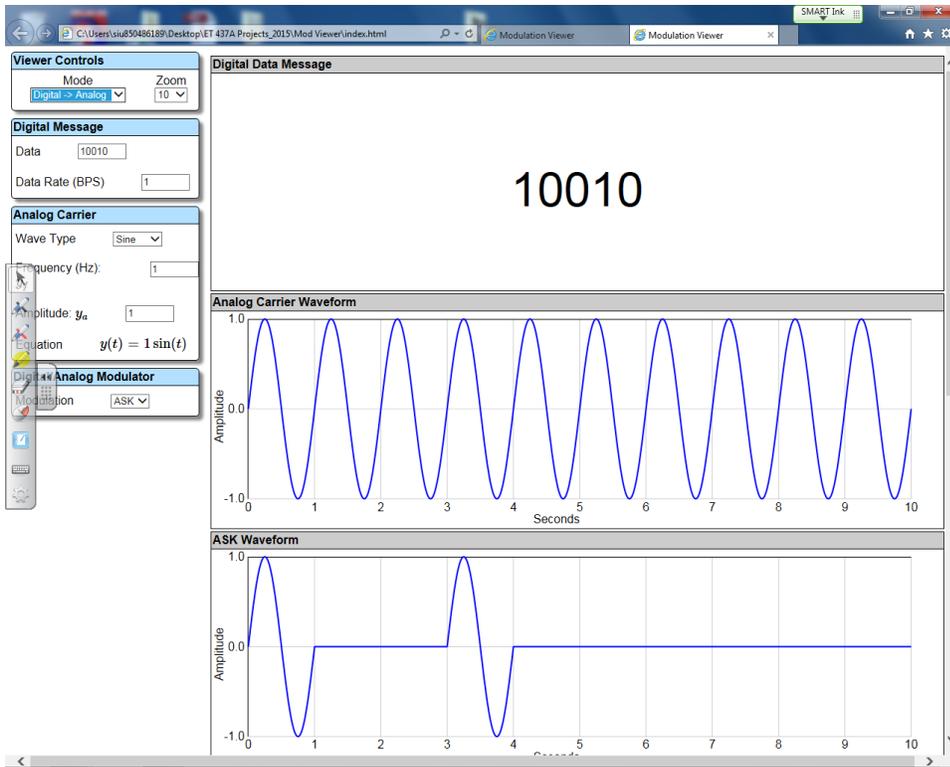Figure 1. EET Communication Simulator- AM Modulation

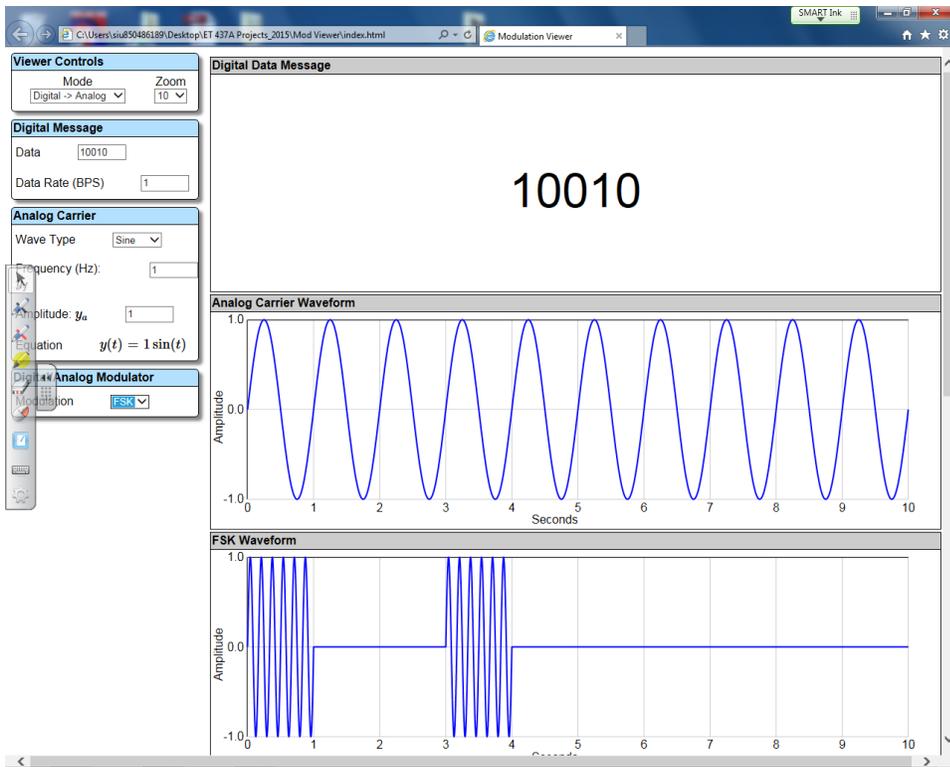**Figure 2. EET Communication Simulator- ASK Modulation**

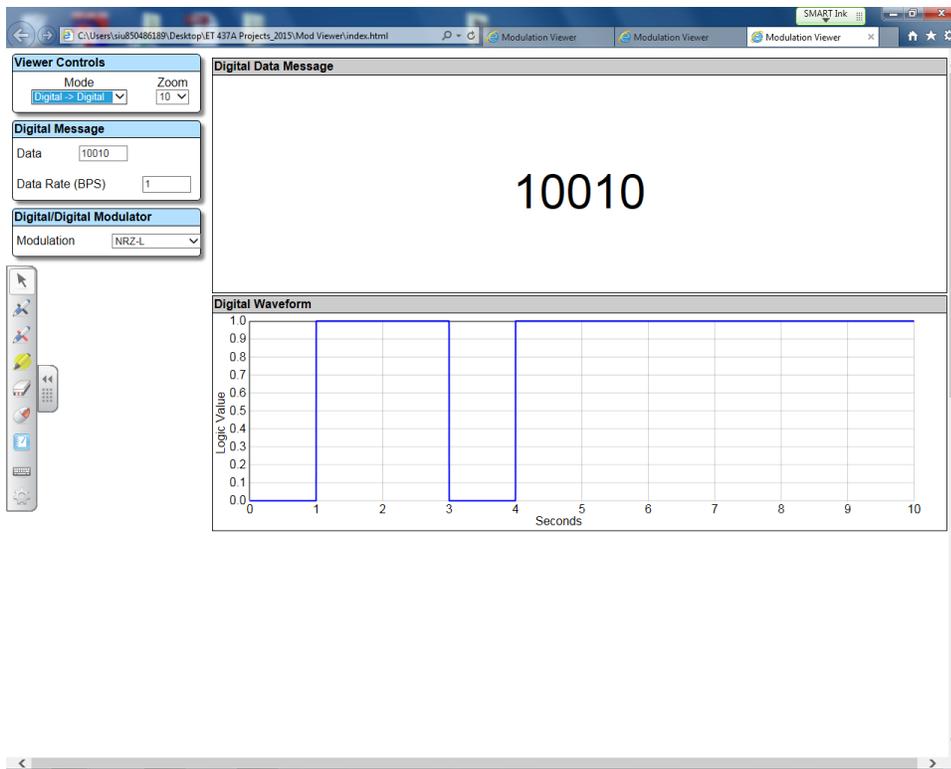**Figure 3. EET Communication Simulator- FSK Modulation**

Figure 4. EET Communication Simulator- NRZ-L Digital Signal Encoding Format

The simulator primarily allows students to visualize analog and digital modulation techniques. Additionally, it enables the user to input digital data and see the visual representations of various digital signal encoding formats including NRZ-L, NRZI, Bipolar-AMI, Pseudoternary, Manchester, and Differential Manchester. The user is able to modify various parameters and see the corresponding visual representation. On the left-hand side (see Figures 1 to 4) of the simulator user interface, the end-user is able to interact with the simulator via the 'viewer controls.' At the beginning, the user typically selects the 'Mode' via a drop-down option box. The mode essentially specifies the nature of the source data (whether analog or digital) and the type of modulation that will be performed on the data (whether analog or digital). For instance, in Figure 1. Analog→ Analog is selected in the mode box. The user interface is dynamic and automatically reconfigures the layout based on what is specified in the mode box. In figure 1, the interface reconfigures the viewer controls so that the end-user can specify the message signal type, frequency, and amplitude. The simulator automatically generates the corresponding signal waveform based on the value of the parameters specified. Similar parameters can be inputted by the end-user for the carrier signal. The modulation technique can be selected in the last viewer control box. Note that the corresponding waveforms for the message, carrier, and modulated signal are displayed to the right. These waveforms although 'frozen' in time, automatically adjust each time the value of the parameters, eg. the frequency, change. Note that the entire interface and allowed parameters options change based on the initial items inputted by the end-user. This can be readily seen by comparing Figure 1 – Amplitude Modulation with Figure 4 - NRZ-L Digital Signal Encoding Format.

Implementation

The final version of the software simulator was written using JavaScript. The two prior versions used MATLAB for one and LABVIEW for the other. JavaScript was used because it provides easy and wider access, since end users only need a web browser in order to execute its code. The simulator was essentially designed to visually display complex mathematical operations via the automatic plotting of graphs corresponding to user inputs. The simulator primarily covers analog and digital modulations. The user is allowed to select various modulation schemes and configure characteristic values related to the message and carrier signal. Also, the simulator displays the corresponding mathematical equations upon which the respective graphs are based, so that students are able to see clearly the change in graph plots as they vary the input values. The simulator is implemented by: (i) writing the codes that represent the mathematical equations for the various communications operations, (ii) plotting these equations to display the visual representation, and iii) allowing the end-user to interact with and change variables of the equations via a graphical user interface. For instance, amplitude modulation is mathematically represented by the following equations:

For a sinusoidal message signal:
$$m(t) = A_m \cos(2\pi f_m t) \tag{1}$$

Carrier Signal:

$$A_C \cos(2\rho f_C)t \tag{2}$$

Modulated Signal:
$$S_{AM}(t) = [A_c + A_m \cos(2\pi f_m t)]\cos(2\pi f_c t)$$
$$= A_c[1 + k\cos(2\pi f_m t)]\cos(2\pi f_c t) \tag{3}$$

where, A_m and A_c represent the amplitude of the message signal and carrier signal, respectively; f_c and f_c represent the frequency in Hertz of the message signal and carrier signal, respectively; t represents time, in seconds, and k is a constant.

The user would be able to see the corresponding equations as he/she selects amplitude modulation in the viewer control panel (see Figure 1). The plots would be automatically generated using default values, if no initial values are inputted. The simulator behaves in a dynamic manner allowing the end-user to modify the values, such as the frequency of the message or carrier signal, and immediately see the corresponding impact on the amplitude modulated (AM) signal plot.

Free Download Available

The simulator along with additional information is available for download at http://www.engr.siu.edu/techproject. Instruction is provided at the aforementioned URL to guide in the download and installation process.

Survey Results and Discussion

A survey was conducted with each year group of students. The primary purpose of the survey was to determine students' attitude towards the simulator. The survey was also used to assess if the objective of the project was met from the students' perspectives. The same survey was conducted 3 separate times with two different year group of students. The first two times were to the same group of students. It was conducted initially mid semester (after 7 weeks) and again at the end of the semester. The next year it was conducted for the third time. This was done at the end of the semester with the second group of students. Each time the survey was conducted the results were shared with the developers so that they could use the students' input to improve the simulator. The Likert scaling was used for most of the responses in the survey. Table 1 below summarizes the result of the last time students evaluated the simulator. The total respondents to the survey presented is 18. However, overall survey respondents were 35 over the two year period (2 separate year groups).

Table 1. Summary of Survey Responses

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. The simulation software layout (interface) is too crowded	0	11.1	5.6	16.7	66.7
2. The simulation software is user friendly	72.2	22.2	5.6	0	0
3. This software is a helpful learning tool for telecommunication fundamentals	61.1	27.8	5.6	5.6	0
4. I would recommend this software to a communication student	55.6	22.2	11.1	11.1	0
5. I would recommend this software to a communication instructor	27.8	55.6	11.1	5.6	0

A few open-ended questions were also included in the survey. These are listed below.

1. Please list any improvements that you think would make the software more user-friendly or a better teaching and learning tool.
2. Please list any important concepts that you think should be included in this simulation.
3. Are there any concepts that should be omitted?

Table 2. Overall Rating

Question	Overall, how do you rate this software?
Terrible if not worse	0
Bad	0
OK	33.3%
Very Good	11.1%
Awesome	55.6%

The results indicated that 94.4% of the students thought that the simulator was user-friendly. Approximately, 88.9% of the students mentioned that the simulator was a helpful tool for learning telecommunication fundamentals. A majority of the students felt strongly enough about the utility of the software simulator to the extent that they would recommend it to fellow students and even to instructors. All of the survey respondents rated the simulator as either okay, very good or awesome. The tool needs a little refinement and a comprehensive evaluation from

professors who teach introductory courses in communication systems. However, the approach using students input as consultants and utilizing their programing skill was very well received and resulted in a fairly satisfactory product. It must be noted that two telecommunication instructors, including one not related to the project, found the simulator to be useful and have utilized it in their classrooms to demonstrate, in a visual way, the signal processing stages in analog and digital modulation techniques.

Conclusion

In this paper a novel approach was used to develop a software educational tool, the EET communication simulator. The simulator was assessed at several times during the development process. Survey results indicate that the project has met its objective by creating a simulator that students can use at their own pace and that helps them in understanding telecommunication principles. Additionally, two faculty have already utilized it in their classroom lectures. Future work could include optimization of the underlying code, including additional features and refining the layout.

References

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