

A Hybrid Lecture/Practice-Based Model for Communication Systems

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Abstract

In this paper, we propose a hybrid lecture/practice-based model for instructing communication systems courses using hands-on activities. In this model, lectures are reinforced using hands-on activities that go hand-in-hand with the main concepts being presented during the lectures. The course is designed to have three hours of lectures and two laboratory hours per week. The hands-on activities performed in the lab are developed using the NI ELVIS II trainer combined with the Emona DATEx add-on board to provide a modular-based system for modeling communication systems. A comparative analysis between two different course offerings was conducted to validate the merits of the proposed model. In this analysis, the control group was a previously instructed course using only simulation and the experimental group was a recently instructed course where this model was implemented. Both quantitative and qualitative assessment methods were conducted and analysis results revealed significant improvement in students' overall performance based on this hybrid lecture/practice-model.

Keywords

Communication Systems, Digital Communication, NI ELVIS, DATEx.

Introduction

In upper-level electrical engineering courses, such as communication systems, students often struggle to understand the fundamental concepts introduced due to their complex mathematical formulations. Therefore, using a hybrid model in which lecture-based instruction is reinforced with practice-based laboratory activities is considered a more effective approach¹. This practice-based learning using visualization and demonstration methodology will allow students to develop necessary inquisitive skills. Simulation-based experiments using software such as MATLAB and SIMULINK have been proposed in the literature to help students visualize complex concepts² and enhance the students' learning process³. However, the extensive programming required to perform these simulations may not only hinder the students' ability to understand these concepts but can also dampen their excitement in the topic discussed. Furthermore, experiments requiring tedious setup procedures will also distract the students from the main concepts being demonstrated⁴. Therefore, a well-balanced approach blending lectures with hands-on experiments will be a more effective model for instructing this course. In this paper, we are extending the scope of previous work⁵ by proposing the utilization of the Emona DATEx add-on board to be coupled with the NI ELVIS II trainer as the platform for this hybrid lectures and practice-based learning model. In addition, we have also developed two sets of experiments that can be used to cover both analog and digital communication courses. These

weekly-based experiments go hand-in-hand with the lectures developed for these courses. Detailed instructions for the Emona DATEx add-on board and the hands-on practical applications are discussed in the following section.

Emona DATEx Board⁶

The Emona Digital Analog Telecommunication Experimenter (DATEx) unit shown in Figure 1 is an add-on board for National Instruments Educational Laboratory Virtual Instrumentation Suite (NI ELVIS) I/II platforms. The DATEx features a hands-on approach to model experiments in both analog and digital communication systems.

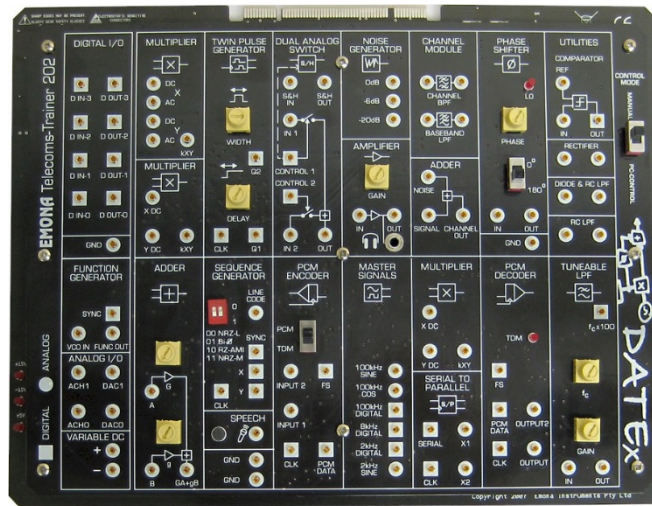


Figure 1- Emona DATEx board

This board provides over 20 independent circuit blocks that can be interconnected using patch wires. These blocks contain digital inputs/outputs, function generator using voltage controlled oscillator (VCO), analog inputs/outputs, variable DC source, multipliers, pulse generator, analog switch and sampler, noise sources, amplifier, channel filters, adders, phase shifter, envelop detector blocks, digital data sources, line coding, microphone, PCM encoder and decoder, quadrature carriers and various frequency clock signals, serial-to-parallel converter, tunable low-pass filter (LPF). The board can be controlled manually through the dials on the NI ELVIS II platform or PC-controlled via the NI ELVIS virtual toolbar and the soft-panel using LABVIEW⁷.

Using this platform, students can model different communication systems simply by wiring together the basic components as they appear in a system block diagram. This system approach helps the students focus on understanding the main concepts taught without being distracted by the nitty-gritty details. Over 13 analog and 23 digital communication experiments can be implemented using a single NI ELVIS II platform with an Emona DATEx add-on board. For more advanced applications, students with good command of LABVIEW can control each DATEx block independently via a set of selectable polymorphic virtual instrumentations (VIs) for the DATEx blocks. Each DATEx block can be independently controlled within a LABVIEW program. This allows students to create “hardware in the loop” systems for advanced processing of signals where measurements are taken via the NI ELVIS, processed in LABVIEW, and the resultant output signals relayed back to the DATEx system.

Communication Course/Lab Models

The Electrical Engineering (EE) program at Georgia Southern University developed two communication courses that cover the analog and digital communication. The Communication Systems course addresses the analog communication while the Digital Communication course covers the digital communication. When these courses were first offered they had a 3-hours/week lecture and 2-hours/week lab components. The lab component primarily used MATLAB simulation. This structure was revised afterwards to follow a hybrid lecture/practice-based model. The EE department acquired 12 Emona DATEX add-on boards with 12 NI ELVIS II platforms to establish a hands-on communication lab as illustrated in Figure 2.



Figure 2- GSU Analog/Digital Communication Lab.

The laboratory experiments listed below are conducted on a weekly basis and go hand-in-hand with the topics being covered during lectures.

Communication Systems laboratory experiments:

- **Lab#1:** An introduction to the NI ELVIS II test equipment
- **Lab#2:** An introduction to the DATEX experimental add-in module
- **Lab#3:** Using the Emona DATEX to model equations
- **Lab#4:** Double Sideband (DSBSC) modulation
- **Lab#5:** DSBSC demodulation
- **Lab#6:** Amplitude modulation (AM)
- **Lab#7:** AM demodulation
- **Lab#8:** Single Sideband (SSB) modulation & demodulation
- **Lab#9:** Carrier acquisition using the phase-locked loop
- **Lab#10:** Frequency modulation (FM)
- **Lab#11:** FM demodulation
- **Lab#12:** Introduction to Armstrong's modulator (Lab#12)
- **Lab#13:** Noise in AM communication (Lab#13)

Digital Communication laboratory experiments:

- **Lab#1:** Sampling & reconstruction
- **Lab#2:** PCM encoding
- **Lab#3:** PCM decoding
- **Lab#4:** Bandwidth limiting and restoring digital signals
- **Lab#5:** Delta modulation and demodulation
- **Lab#6:** Delta-sigma modulation and demodulation
- **Lab#7:** Amplitude Shift Keying (ASK)
- **Lab#8:** ASK demodulation using product detection
- **Lab#9:** Frequency Shift Keying (FSK)
- **Lab#10:** FSK generation (switching method) and demodulation
- **Lab#11:** Binary Phase Shift Keying (BPSK)
- **Lab#12:** Quadrature Phase Shift Keying (QPSK)
- **Lab#13:** Signal-to-Noise ration and eye diagrams
- **Lab#14:** Spread Spectrum - DSSS modulation & demodulation

Sample Experiment (Double-Sideband Suppressed-Carrier Modulation/Demodulation)⁸

In communication systems, message signals get modulated to different frequency bands for easy transmission and to allow multiplexing and better utilization of the communication channel.

Like amplitude modulation (AM), Double-Sideband Suppressed-Carrier Modulation (DSB-SC) uses a microphone or some other transducer to convert speech and music to an electrical signal called the message or baseband signal. The message signal is then used to electrically vary the amplitude of a pure sinewave called the carrier. And like AM, the carrier usually has a frequency that is much higher than the message's frequency as illustrated in Figure 3.

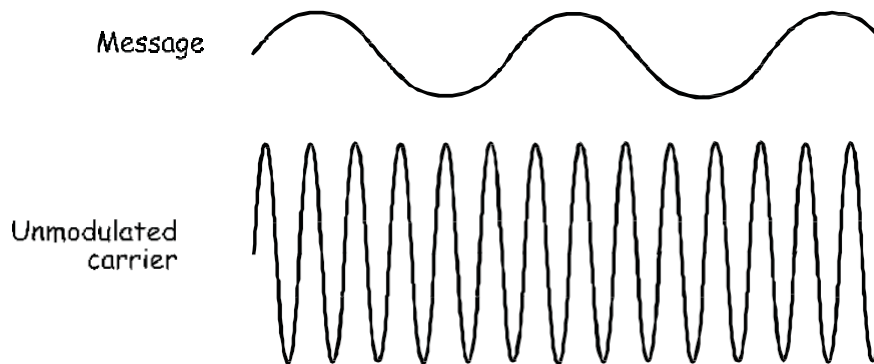


Figure 3- Message and Carrier Signals

In the lecture part of this experiment the mathematical model for the DSB-SC modulation is defined as follows:

$$S_{DSB-SC}(t) = m(t)\cos(\omega_c t) \Leftrightarrow \frac{1}{2}[M(\omega + \omega_c) + M(\omega - \omega_c)]$$

The modulated DSB-SC signal is illustrated in Figure 4. The dotted lines added to track the signal's envelopes (that is, its positive peaks and negative peaks). If you look at the envelopes closely you will notice that they are not the same shape as the message in the case with AM.

When the message is a simple sinewave (like in Figure 3) the equation's solution (which necessarily involves some trigonometry) tells us that the DSB-SC signal consists of two sinewaves:

- One with a frequency equal to the sum of the carrier and message frequencies
- One with a frequency equal to the difference between the carrier and message frequencies

Importantly, the DSB-SC signal doesn't contain a sinewave at the carrier frequency. This is an important difference between DSBSC and AM.

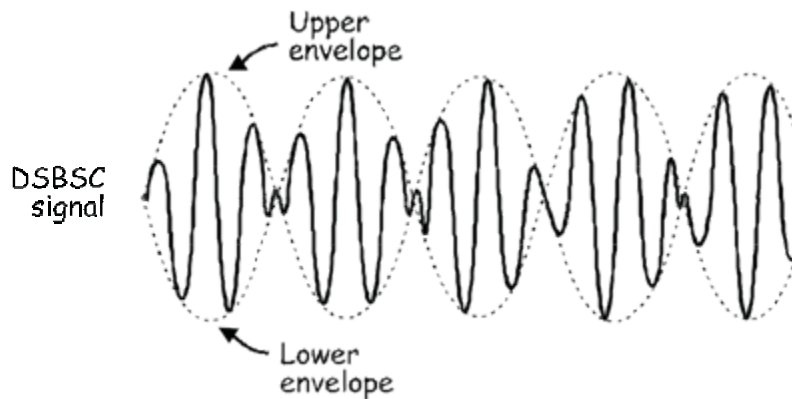


Figure 4- Double Sideband Suppress-Carrier (DSB-SC) Modulated Signal

For this experiment, you will use the Emona DATEx to generate a real DSBSC signal by implementing its mathematical model. This means that you'll take a pure sinewave (the message) that contains absolutely no DC and multiply it with another sinewave at a higher frequency (the carrier). You will examine the DSBSC signal using the scope and compare it to the original message. You will do the same with speech for the message instead of a simple sinewave.

In the next step, you will vary the message signal's amplitude and observe how it affects the carrier's depth of modulation. You will also observe the effects of over-modulating the carrier.

The DATEx DSB-SC experiment setup illustrated in Figure 5 model the DSB-SC block diagram illustrated in Figure 6.

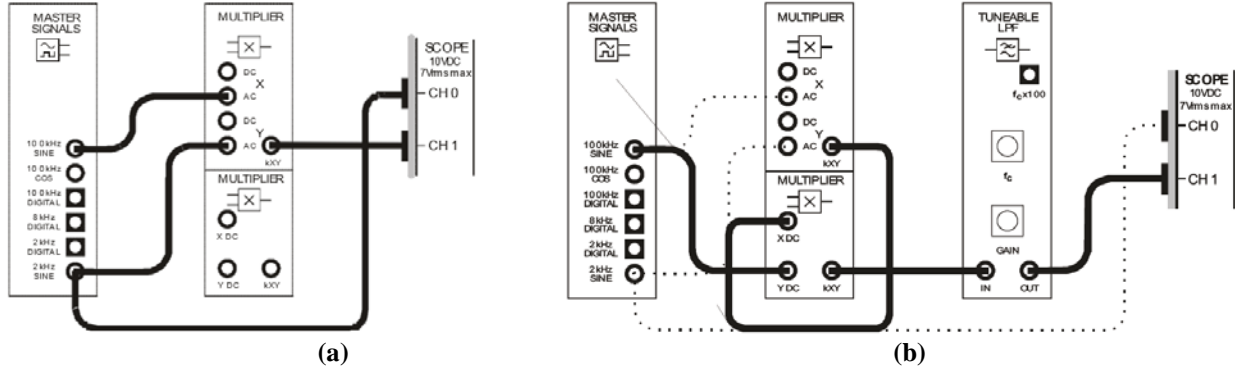


Figure 5- Double Sideband Suppress-Carrier DATEx Experiment Setup (a) Modulation (b) Demodulation

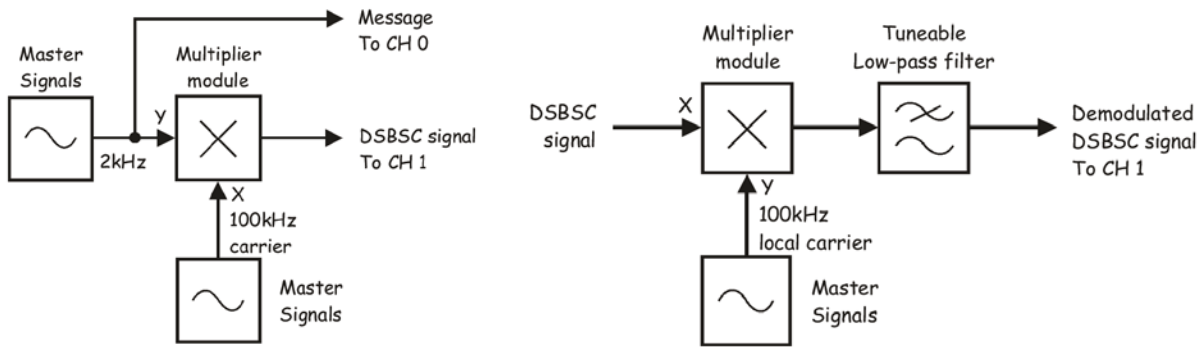


Figure 6- Block Diagram of Double Sideband Suppress-Carrier (a) Modulation (b) Demodulation

The physical setup of the DSB-SC modulation and demodulation experiments using the Emona DATEx board are illustrated in Figure 7.



Figure 7- Physical Setup for DSB-SC (a) Modulation (b) Demodulation

Using the NI ELVIS Instrument Launcher (see Figure 8), the students were able to visualize the time-domain original message signal, DSB-SC modulated signal, and the demodulated message signal by using the scope as illustrated in Figure 9.

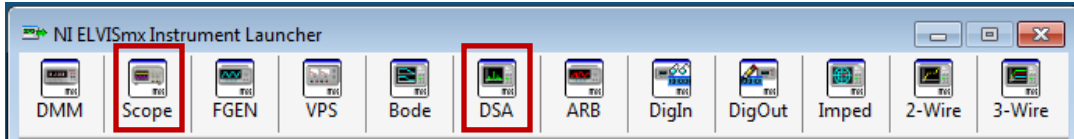


Figure 8- NI ELVIS Instrument Launcher highlighting the Oscilloscope and the Digital Spectrum Analyzer

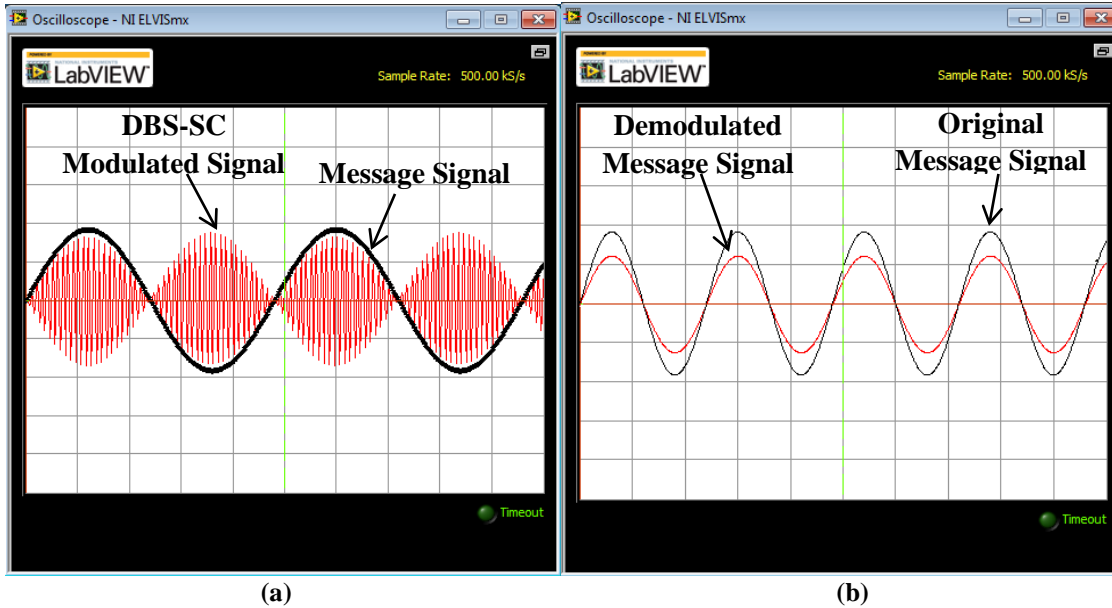


Figure 9- Oscilloscope output (a) Message & DSB-SC Signals (b) Demodulated Message Signal

In addition to the time domain representation of the signals, the students used the spectrum analyzer in the NI ELVIS Instrument Launcher to visualize the frequency-domain spectrum of the original message signal, DSB-SC modulated signal, and the demodulated message signal as illustrated in Figure 10.

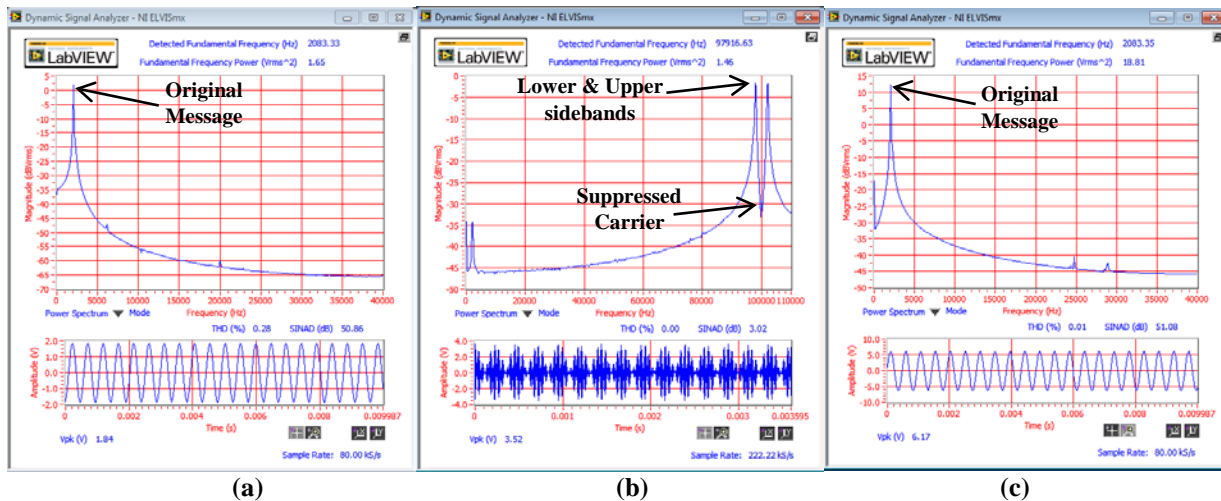


Figure 10- Spectrum Analyzer output (a) Message (b) DSB-SC (c) Demodulated Message

Assessment of Implementation Impact

The effectiveness of these lab models using the Emona DATEx was qualitatively and quantitatively assessed. For qualitative assessment, a survey consisting of the following seven questions was conducted towards the end of the semester in both the analog and digital communication courses.

- **Q.1:** Were the lab equipment (NI ELVIS with Emona DATEx) user friendly/easy to use?
- **Q.2:** Do you prefer using hands-on based experiments using the Emona DATEx system over a software-based experiments using MATLAB?
- **Q.3:** Did the experiments aid in your understanding of the course material?
- **Q.4:** Did the lab instructions provided discuss the theory related to the experiments?
- **Q.5:** If you were to rank this lab among different labs you have already taken in other courses, how would you rank this lab?
- **Q.6:** If you were to take this course again, would you recommend adding more experiments?
- **Q.7:** Did the instructor have the required knowledge to supervise this lab?

The responses to the survey reported in Figures 11 show the average rating on a scale of 10 and their corresponding standard deviation represented by the error bars. As depicted, the students in both courses reflected a high-level of satisfaction with the Emona DATEx system used for experimentation. From responses to question 2, it is evident that the students preferred the hands-on approach over the software simulation approach. On the other hand, the students didn't conclusively agree on whether to add more experiments or not as reflected by the large standard deviation of question 6. However, the majority of students didn't recommend adding more experiments as indicated by the low average response to question 6.

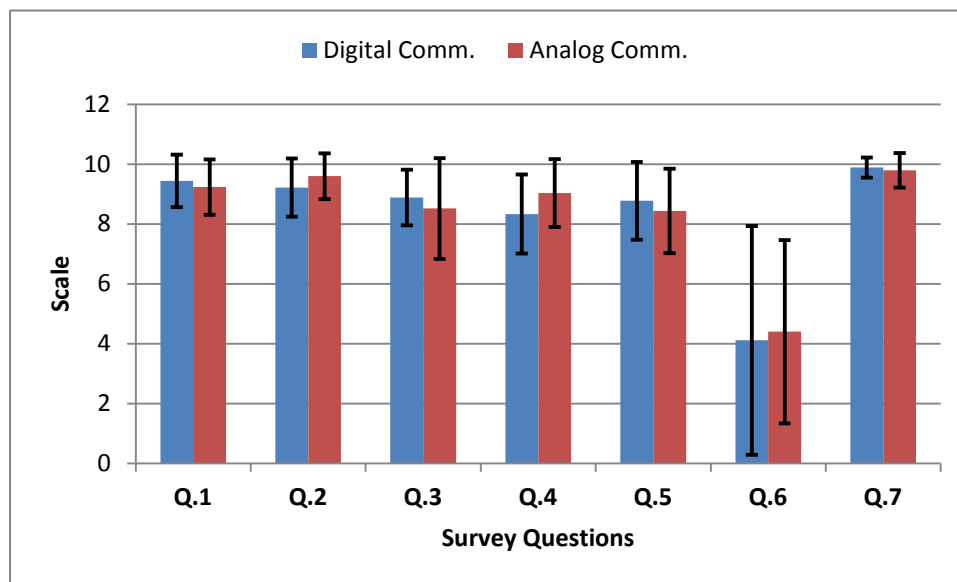


Figure 11- Student Survey Average Responses and their Corresponding Standard Deviations

Furthermore, the students' performance was assessed using a quantitative analysis. A similar exam was administered in two courses offerings by the same instructor. The first course (control group) used software-based experiments using MATLAB while the second course (treatment group) used the proposed hands-on Emona DATEx add-on board coupled with the NI ELVIS II platform. Figure 12 demonstrates the normal distribution fit for the performance of 14 students in the control group and 29 students in the treatment group. As depicted from Figure 12, there is a significant difference in the overall average with the treatment group scoring higher by almost 1.8 points on average. In addition, the standard deviation exhibits less variation in the treatment group grades compared to the control group. This is an additional indication of how the proposed system positively impacted the students' understanding of the topics discussed which is reflected in their performance.

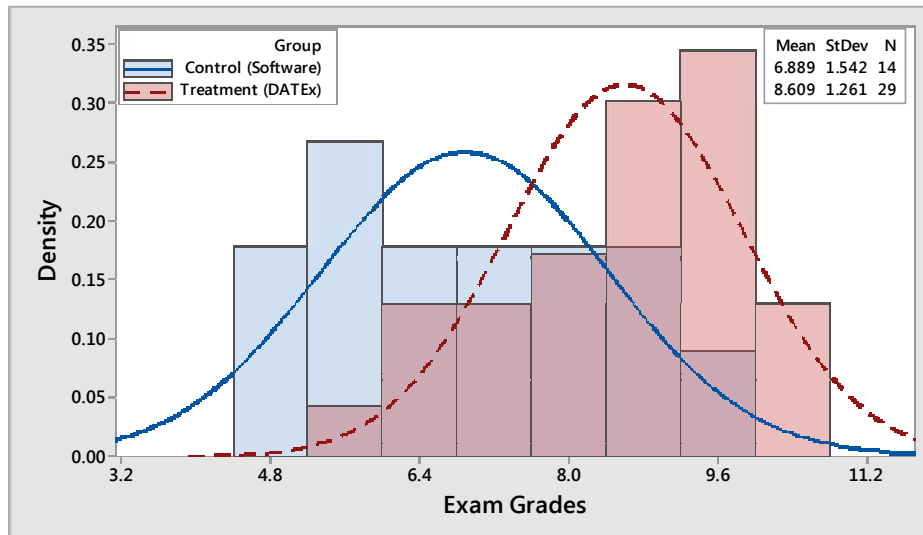


Figure 12- Fitting the Control & Treatment Groups' Exam Grades into Normal Distributions

A detailed statistical analysis of the exam results was conducted using the Minitab statistics software⁹. The null hypothesis indicating no statistical difference in exam grades between the control and treatment group was assumed. The General Linear Model was used to test this hypothesis and analyze the data with a probability criterion of 1% ($p=0.01$) significance level. If the analysis generates a p-value less than the 0.01, then the null hypothesis is rejected meaning that the proposed hands-on lab model is in fact helping improve the students' performance. The response variable was the students' exam grades in both the control and treatment groups. The statistical analysis generated a p-value of **0.000355** which is much smaller than the **0.01** criterion to test significance. Therefore, the null hypothesis was rejected with over **99.96%** confidence level indicating statistically significant difference in the students' performance between the control and treatment groups. In addition, the calculated Cohen size effect (d) of **1.268** indicates that the proposed approach has a significantly large effect on the students' performance.

To further investigate this conclusion, a Tukey pairwise comparison with a confidence level of **99%** was conducted as illustrated in Figure 13. This comparison strongly supported our conclusion that exam results in both groups were statistically different. It also indicated that, on average, the treatment group scored higher than the control group on average as a result of using the proposed model.

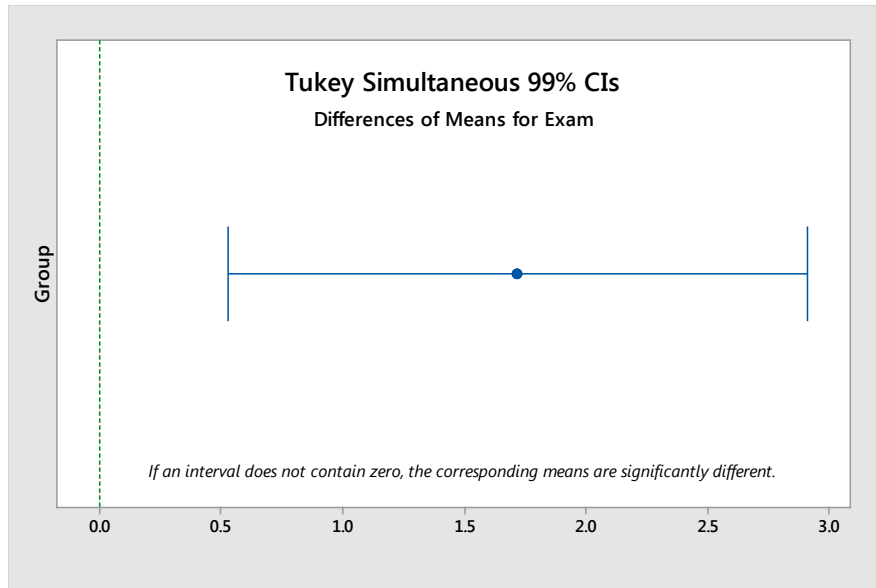


Figure 13- Tukey 99.0% Simultaneous Confidence Intervals

To test the model's goodness of fit, the probability plots of both groups' grades were plotted in Figure 14. As shown, the data points relatively follow the straight line generating p-values over 0.05 with a low adjusted Anderson-Darling statistic (AD). This implies that assumption of normally distributed grades was accurate for both the control and treatment groups.

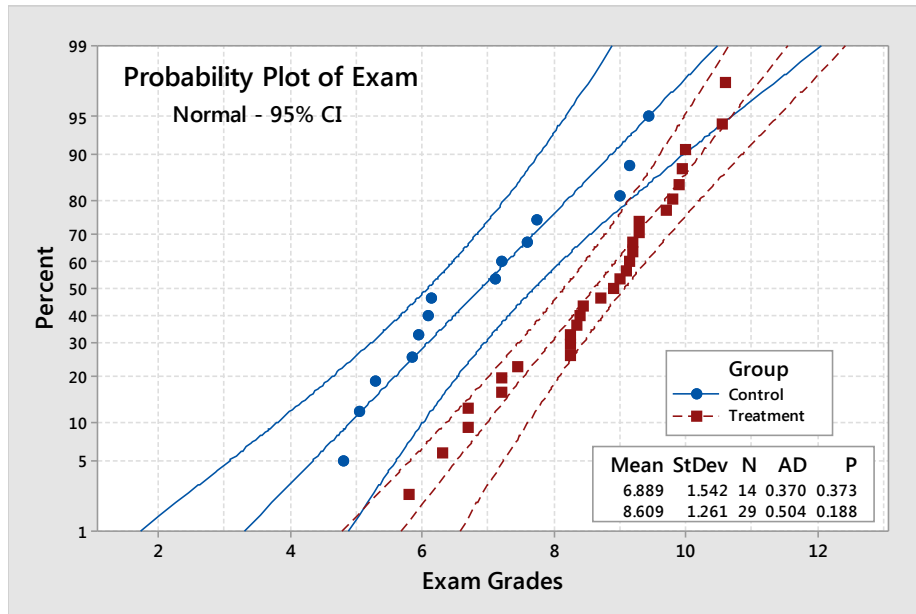


Figure 14- Probability Plot of Control/Treatment Groups

Conclusion

In this paper, a hybrid lecture/practice-based model was proposed for instructing communication systems courses using hands-on activities. As expected, this practice-based learning model using visualization and demonstration methodology helped students develop necessary inquisitive skills. In addition, this model helped the students get excited and stay focused on the topics

covered. Using this hybrid model, topics covered in lectures are reinforced with hands-on activities that go hand-in-hand to help students understand complex concepts. The courses were designed to have three hours of lectures and two laboratory hours per week. The hands-on activities performed in the lab were developed using the NI ELVIS II coupled with the Emona DATEX add-on board to provide a modular-based system for modeling communication systems. In addition, the models of two communication courses with their corresponding labs were presented. A sample experiment to modulate and demodulate a message signal using DSB-SC was demonstrated. A comparative analysis between the two different course offerings was conducted to validate the proposed model. In this analysis, the control group was a previously instructed course using only simulation while the experimental group was a recently instructed course using this model. A quantitative assessment was conducted and the analysis results revealed significant improvement in the students' overall performance based on this hybrid lecture/practice-model. In addition, a survey conducted towards the end of the semester reflected the high level of students' satisfaction that warrants the use of the proposed model in future engineering course offerings.

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