Diagnose, Analysis, and Proposal of Project Based Learning (PBL): A Case for Analog Communications Course

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Abstract*– This paper makes a diagnose, analysis, and proposal of PBL, focusing on different strategies to overcome weakness in the theoretical background from the signal and systems curriculum that is crucial for an analog communication course. The strengths, weaknesses, opportunities, and threats (SWOT) matrix was used as a tool to diagnose the results on learning using the traditional curricula. An analysis of surveys to students after finishing their courses during three semesters, suggests that due to the lack of context, the math applications using fundamental concepts (i.e., Rayleigh and Parseval theorems) forced the students to face difficulties in understanding the basics of signal analysis. The proposed PBL design focuses on students face little challenges (sub-problems) related to the implementation of a radio transmission system. Then, through different operations and modeling of distortive phenomenal on signals as key elements, the effect was to approach real-life scenarios and enhance the students' knowledge and skills. The project was executed by using programming Universal Software Radio Peripherical (USRP) devices and GNU Radio to validate the transmission for amplitude modulation (AM) and frequency modulation (FM). This proposal, as a first trial in the telecommunications area, seeks to motivate students and evaluate the adoption of the PBL methodology. The experience will be conducted for two more semesters looking for consolidating the theoretical and experimental skills through validation of the fundamental concepts used in analog communication systems.

Keywords—Project-Based Learning, Analog Communications, SWOT Analysis.

I. Introduction

The education is a crucial element for the social, cultural, political and economic transformation and development of any nation. Therefore, effective teaching is also essential to help children, teenagers, young people, and in general people, to evolve from one level of knowledge to another, interacting in a specific environment to form in their minds an independent way of learning [1]. While traditional methods rely mainly on textbooks and the whiteboard as the main scenario to explain sequential topics and test for problem-solving; the modern teaching and learning methods make use of hands-on materials like content cards, searching strategies for selection of papers and references, conceptual maps to synthesize and present results in a clear and concise way, and of course, the use of new methodologies and pedagogical strategies to achieve goals through activities in a macro problem solving as main challenge.

Today, due to the dynamic evolution of technological devices a lot of distractors may interfere with the learning process if an adequate use of these tools is not included in the teaching and learning in the classrooms. Then, to take advantage and motivate the use of all these assistance tools may lead to better construction of knowledge, avoiding the anxiety that produces the application of tests required to evaluate the teaching based-on contents. In [2] a framework for using game theory tournaments as a base to implement competition-based learning was used to motivate the students and increase their learning performance. Also, a description of the learning activities performed during ten years with a survey analysis feedback from the students, suggest that the combination of game theory and friendly competitions provides a strong motivation for students helps to increase their performance. In this same area, the paper in [3] presents a PBL experience to design mobile communications based on a competition among teams to obtain the best network design for the budget, emulating an imaginary mobile operator. Also, another approach presented in [4] shows that due to the lack of interest in studying science and technology programs, an example of curriculum design pursues to enroll students through a PBL oriented lab for systems, control and information technologies with the challenge of sustainability and green development. The work uses Web 2.0 to improve communication and collaboration in the PBL framework.

On the other hand, reference [5] devotes to a PBL lab using wireless sensor network (WSN) with the objective of learning to code sensor nodes, simulate the deployment of nodes, analyze the power consumption, and the communication protocols used to make real connections to smart cities (electric and water distribution systems or traffic-lights control). The PBL methodology has proven to achieve the necessary skills to develop services and applications in the context of smart cities. Other work presented in [6] addresses a PBL challenge study at technical high school to build an artificial satellite, and a positional-based system using general purpose wireless devices (ZigBee IEEE 802.15.4). This study was aimed at the improvement of the teaching method in the electronics and electrical engineering curriculum, and as an important result, the methodology shows evidence of learning skills and student enthusiasm to learn. Another proposal [8], addresses, as main objective, to develop techniques for effective teaching of computer network design. The design of the PBL thread exploited the practical experience of the module facilitators and allowed the students to play the role of network design consultants, working on a total of three scenarios that had a strong practical dimension and realism. Evaluation of this PBL thread has indicated generally strong support from the student season, reflected in an encouraging set of results obtained from the network design assignment. Finally, in [8] the authors propose a PBL model for control system education thinking in facilitating learning, encouraging the development of transversal skills from technical areas of engineering programs, and responds the questions of how to apply PBL in single courses as part of the traditional education curricula. The approach considers that the students living in particular context (culture and customs of the region), where the university is located need to recreate professional challenges and boost the teams to solve a specific control system problem.

With this review, an important issue to analyze are the opportunities that offer the PBL in different knowledge areas, but a diagnosis is relevant to identify and design the way of introducing the key concepts, linking the theoretical background to the practice and achieving a learning experience with team interaction to develop a complete analog transmission scenario. This paper, in section II, put in context the application case, then in section III makes a diagnosis and analysis through the SWOT matrix. Then, in section IV, a proposal of PBL model-centric on problem-solving is presented, including the syllabus and content card adapted to the methodology, and finally, the conclusions summarize the analysis and the trial to perform.

I. The application case: Analog communication systems

Analog communication course in the Electronic Engineering curriculum is an important subject that addresses the transmission and reception of information signals in continuous time domain, propagated through different channels (wired and wireless) in the form of electromagnetic waves. The three key elements that build a conventional transmission scenario are: *i*) the transmitter, *ii*) the channel, and *iii*) the receiver. A brief description tells us that at the transmitter, an analog source (a variable that models a physical phenomenon, the voice, piano or guitar sounds) serves as a source to generate a continuous time-varying waveform (signal). After that, the modulator changes some parameter of the message signal (the amplitude, frequency or phase) as a function of a carrier signal with a higher frequency comparing to the frequency of the message. Then, an electrical signal that represents the message is delivered to the channel through an antenna, as the transitional structure between the guiding device (e.g., waveguided or transmission line) and the free-space. The noise modeled as a random process is an essential part of the system that mixes and degrades the message signal introducing distortion or spurious (spectral components in the frequency domain) that limits the system performance, and the quality of the estimated received message. It may appear in any part of the three key elements that constitute the communication system, this effect is due to imperfections on the manufacturing of devices, use of higher-level power that introduce distortions, and also due to non-linear structures used at the transmitter or receiver sides. Finally, at the receiver, the signal is amplified, filtered and recovered using different receiver architectures to obtain an estimated version of the transmitted message.

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II. Diagnosis of Analog Communication Course

After surveying during three semesters asking to students for weakness, skills, and knowledge required, researchers build a SWOT analysis matrix to understand how evolves the learning process. As a result of this analysis, a proposal of a PBL design is presented for an analog communications course thinking in learning specific and transversal skills that improves the performance of students and their knowledge through both theoretical and practical experiences. In table I, a summary of the answers given by the students on the survey, remarks about the difficulties and strengths showing the main aspects to analyze how to propose the PBL design. From the SWOT matrix, researcher could conclude that the main disadvantage and reason of low performance is the ‘lack of linking the applications of signal analysis topics (Fast Fourier Transform (FFT), power, energy, and auto-correlation concepts, theorems, and properties) in the telecommunications area’, and how to relate the math process with the tasks required for implementing the modulation and demodulation stages. Likewise, from Table I, students highlighted that have good skills to solve mathematical problems by calculating integrals, derivatives, and even programming capabilities, but not under free license environments.

TABLE I
SWOT matrix from student surveys.

Strengths	**Weakness**
Skills to solve problems related to signal analysis Cooperative working and teamwork Information searching	The absence of programming skills (Python, Matlab, ScyPi, GNU Radio flowgraphsetc.) Lack of linking between concepts on signals and systems applications Filter design, implementation, and testing with real signals Linear time-invariant (LTI) block system operations in the context English writing and speaking
Opportunities	**Threats**
Identification and classification of information to develop system models Improve English language competence Improve language programming skills Development of soft skills in a holistic approach	Resistance to read, writing and present in public topics in English Desertion Traditional education Inertia

Also, they mentioned feeling fear to speak in public due to there are few experiences on the campus to do that. As a result of the desired learning process, the main task in the definition of a project is related to the definition of sub-problems according to the syllabus. Therefore, two practical and important skills must be defined before the proposal of PBL: *i*) to develop search criteria and domain of reading comprehension to synthesize important facts, and *ii*) to adopt good practices to create prototype demonstration.

The next step is to find a way to integrate those skills into specific problems, that mandatory should be addressed to advance on the different stages of the analog communication system to achieve the challenge of theoretical knowledge and experimental validation by using the USRP devices.

III. Proposed PBL Model

An important issue with the PBL is related to the work assessment that must be wide in the sense of providing feedback to follow the numerical validation and physical implementation of a prototype. In Fig. 1, five key elements are proposed to develop different skills on the students. At the center, the problem-solving challenge look-for getting the ability to interpolating that specific knowledge to a wider context. Also, takes feedback from the professor and other students to solve problems indirectly and with a creative focus, proposing innovative solutions.

Besides, the criticality seeks for learning from incomplete information on particular topics, to inspire the searching of crucial scientific/engineering information, to identify and select the main references to analyze, rethink, and build proper knowledge. Finally, some remarks to development academical, personal and professional abilities are proposed to enhance the integral formation as human beings.

TABLE II
Important Skills Desired in the Learning Process

Skills	Description
Search criteria and synthesize important facts	Additional to main references on the syllabus, the student must be able to define some search criteria to find and identify relevant scientific and engineering problem solutions, learn to select relevant papers, book-chapters, datasheets, and diagrams, within others, and synthesize the key elements on the subject to report them in a clear and concise report it preferable in English (native language is Spanish).
Develop good practice to create prototype demonstration	From the previous desirable skill, the knowledge apprehension is enabled by implementing models/block diagrams under numerical computation platforms or in physical prototype demonstrations. Therefore, a good engineering practice consists of the ability to analyze context information on specific topics and develop simulation and physical implementations to validate models, concepts and math theorems applied in analog communications systems.

On the academic part, searching, selection, synthesis, and reporting of information both oral and written are highly desirable. Agile math thinking for predicting possible results, and information analysis and programming skills are also welcome. On the personal and professional development, time management and strategies for learning i.e., for life-long learning, the studying has to take place in smaller chunks over time, bringing information to mind without use class material, explain and describe ideas with detail, switch ideas while studying, and use specific/daily examples to understand abstract ideas. Besides, other strategies such as teamwork and working on groups, collaboration, decision-making, leadership, and proactive thinking contribute to higher opportunities for employment.

A. Practical PBL implementation

According to the syllabus defined for 16 weeks per semester, the following proposal look-for building different blocks per stage of implementing an analog communication system:

- Six to eight problems to consolidate the theoretical background but including numerical validation distributed as 1×1 week, 5×2 weeks and 2×3 weeks.
- Two problems including hardware (USRP) implementation and addressing design issues
- Teams grouped up to 4 students with a speaker

B. Requirements and lab facilities

- Room with computers (internet access), Python, GNU Radio, and USRP devices per team (Active learning classroom)
- Whiteboards and markers

Fig. 1. Key skills to evaluate in PBL.

- Tables and chairs
- Selected didactic material: signals and systems practical guideline for Octave, SciPy, Matlab, Python, etc., signal generation and math operations between signals, channel modeling, noise, and videos of how using block diagram is possible to build the modulator/demodulator, within others.
- Internet access

However, some pre-requisites and material must be available before start working.

- What is PBL?
- Why use PBL?
- What to expect from advisors and students?
- Key skills: which definitions and source of evidence, formats, and resources will be collected during the process?
    - Which will be the group-works?
    - Which are the milestones and deadlines?
    - How to assess and feedback?
    - A portfolio to collect the evidence of work
    - The syllabus including the PBL methodology per week
    - Resources guide
    - Policies, grades, and penalties.

Besides of permanent advisory, two workshop days at the beginning of the semester (first week), and another, after mid-term (eight weeks) is required to observe the evolution and challenges per teams and to clarify possible misconceptions of the final project.

C. PBL TIMELINE

- Each problem will require approximately ten hours of work per week including facilitation.
- A short meeting class to introduce the problem and orientate the workgroup, including a small description of the problem, tools to work with, etc., which will give students a general idea and view of the challenge.
- During advisory possible suggestions to focus on the topics would include motivational lectures or book-chapters.
- A facilitator or monitor (senior students) with experience on the subject will assist and coordinate the group sessions at the lab.
- The information will be gradually given to solve the problems and force database reference searching, reading, classification and identification of research teams, institutions, and researchers working on the topics. However, some meetings based-on specific questions will provide additional information to identify errors and support students to build the models correctly.

D. ASSESSMENT

- In a portfolio, all work evidence (reports, lab guides, presentations, and implemented models) related to problem-solving will be collected to assess the PBL course. Some problems will demand higher work and require divide-and-conquer strategies to achieve the goal; besides that specific works will have a different weight depending on the challenge.
- The evaluation is applied with complete participation of all the students of the workgroup. Besides, each student must present and answer the questions with criteria and supported with the developed tasks on the portfolio.
- Assessment design will consider 50:50 between the group and individual work.
- An important issue is that like in the conventional syllabus, a set of topics must be re-organized as a function of their relevance, dedication time, work, and ways to develop the modulation/demodulation models.

E. ANALOG MODULATION TOPICS

Signals and systems: energy and power concepts and calculation (Parseval and Rayleigh theorems), FFT for one-sided and two-sided spectrum estimation (periodogram), rotating and stationary phasors, low-pass and bandpass equivalent model, spectrum translation, convolution in time-domain and product on frequency-domain, filtering (low-pass and band-pass, high-pass), transfer function and frequency response, signal distortion, equalization, autocorrelation, spectral density functions, and Hilbert transform.

Amplitude modulation (AM): amplitude modulation scheme, double sideband (DSB), single sideband (SSB), and, vestigial sideband (VSB). Modulation and demodulation for each scheme, percentage modulation, transmitted and received power, bandwidth, switching mixers, distortion, and non-linear modulators.

Frequency modulation (FM) and phase modulation (PM): modulation index, bandwidth, frequency spectra, choice of modulation index, narrow band FM, noise in FM systems, threshold levels; modulation and demodulation (wideband, narrowband, pre-emphasis, de-emphasis, frequency division multiplexing (FDM).

Noise: Definition of noise figure, noise figure for the mixer and intermediate frequency (IF) amplifier, radio frequency (RF) amplifier followed by the super-heterodyne receiver, and system noise temperature. Thermal noise, shot noise, and 1/f

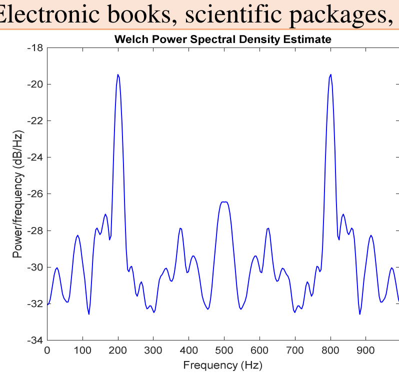
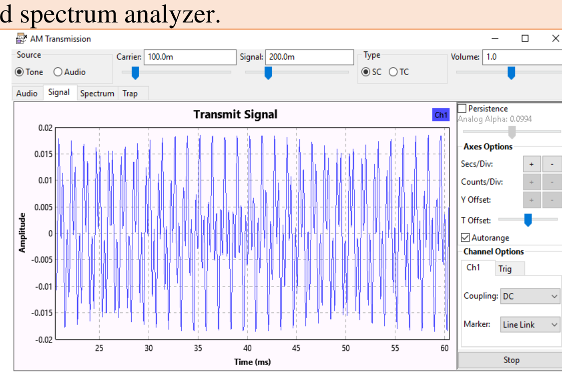
CONTENT CARD: PARSEVAL THEOREM FOR POWER ESTIMATION OF PERIODIC SIGNALS	
Technical competences summary	▪ Relation of the average power of a periodic signal to its Fourier coefficients ▪ Spectral interpretation of signals in the frequency domain ▪ Superposition principle of average power
Objectives	▪ To estimate the power for periodic signals using the Parseval theorem and signal analysis in the spectrum analyzer
Contents	▪ Fourier analysis ▪ Exponential Fourier series ▪ Fourier transform
Learning outcomes	Students should be able to: ▪ Apply integration/summation to calculate Fourier coefficients ▪ Obtain the percentage of power contained in a limited number of harmonics ▪ Validate the results of the calculated power level by using scientific software ▪ Computation of the power density spectrum from the squared Fourier amplitudes ▪ Relate the noise variance of a variable like a sum of powers ▪ Plot spectra of signals and obtain the power for a limited number of harmonics ▪ Use GNU Radio measuring of level powers for the signals analyzed – Parseval theorem demonstration
Learning resources	Electronic books, scientific packages, and spectrum analyzer.
Hands-on	 The double-sided spectrum of the sinusoidal signal.  GNU Radio flowgraph showing Amplitude Modulation.
Evaluation	Theoretical exam and analysis of signals using the spectrum analyzer, portfolio, workshops, written report and oral presentation.

Fig. 2. Content card example for Parseval theorem application

noise. Noise in analog modulation systems, noise in AM systems, and noise in FM systems.

F. CONTENT CARD

From [8] the use of content cards helps to describe the stages of the project related to the syllabus, contents, learning objectives, deliverables, and tools for supporting each topic. However, content cards by itself are not a guideline for the project execution but assist the professors in addressing the learning process and linking the content with the project. Besides, like the PBL model is student-centric in Fig. 2 a proposal of the content card for signal power estimation using Parseval theorem is described. On the hands-on session, the result of the simulated signal spectrum is shown on the left, and, a real amplitude modulated signal is observed in the USRP radio teaching us *i*) the feelings of radio signal modulation and its effect on motivation for the students, and, 2) the importance that offers the experimental validation to develop knowledge.

IV. CONCLUSIONS

This paper proposes a diagnosis, analysis and proposal PBL model to provide connection of the theoretical foundations with hands-on lab tools to implement an analog transmission system built from zero using GNU Radio and USRP devices. A novel application of SWOT matrix allows identifying the key elements that require attention to advance in the activities and tasks, for achieving the goals in each stage of the construction of the modulator and demodulator. Besides, following the principles of PBL a proposal of key skills with core "Problem solving" inspire us to develop a design of PBL in the field of telecommunications. A description of the practical implementation, lab facilities, timeline, assessment, and topics of the syllabus is presented for a particular case of signal analysis as exemplification. Finally, a content card shows how it can be developed for a specific topic consolidating theoretical and experimental skills. With this proposal, a trial was conducted mainly to analyze the weakness by students' feedback from surveys applied during three semesters, and as a first important achievement worth to highlight the SWOT analysis serves to rethink the teaching and learning process in the engineering courses.

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