WIP: Use of a Self-Executing Notebook Based on Matlab's Live Editor for the Development of Autonomous Learning Competency in an Analog Communications Course

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Abstract*—This innovative practice WIP paper describes how autonomous learning competency is developed in a course called "Communications Theory 1" that covers analog communications topics within the Telecommunications Engineering Program. To this end, all course material has been redesigned as a self-executing notebook using Matlab Live Editor[1] and is delivered chapter by chapter throughout the semester. This allows students to read the course content and interact with the simulations, modifying them freely to explore the session theory in greater depth and, finally, recognize relevant limits and characteristics. Within the course platform, based on Moodle, the contents have been accompanied by exercises in the Matlab Grader model, which allow feedback to the student when answering the questions provided, validating the developed code. This work helps to strengthen their knowledge in parallel to the activities carried out in the classroom. Since the self-executing notebook provides the information necessary to understand the behavior of the different analog communication techniques seen in the course, in the final chapter, all the knowledge is integrated into an activity that combines the flipped classroom and the puzzle technique, allowing students through teamwork, fully develop the final chapter of the course with a high level of autonomy. This work will be evaluated with the support of rubrics that will allow us to know its progression in the different learning outcomes related to the specific competencies developed in the course and the advancement of generic competencies, including autonomous learning. As a work in progress, initial measurements in applying the self-executing notebook indicate high student satisfaction with the notebook's content and the associated activities. Additional assessments are then planned to refine the teaching-learning cycle and improve course outcomes. Finally, new activities are proposed to complement the training by applying AI technologies and using new laboratory resources.

***Keywords*—competence, rubric, higher education, electrical engineering, computer-based instruction, flipped classroom**

I. Introduction

Autonomous learning is recognized as a generic competence in which "the person should take the initiative in his learning process, have a diagnosis of the learning needs with or without the help of third parties, set learning objectives, identify human and material resources that allow the achievement of objectives, selection, and implementation of adjusted learning strategies, self-evaluation of the learning effects." according to [1]. This means that educators must design learning opportunities that students can utilize throughout the course and spaces where students can apply their learning to achieve more significant goals.

At the Pontifical Catholic University of Peru, within the educational model published in 2021 [2], the generic competence of autonomous learning and adaptability has been defined, in which the student manages his learning process autonomously, using digital and informational resources. Likewise, it adapts to the changing conditions of the environment, assertively proposing solutions to conflicts. This generic competence is part of the six competencies the PUCP has adopted in its educational model.

In this context, the telecommunications engineering program has a competency-oriented study plan in which generic competencies, including autonomous learning and adaptability, are repetitively incorporated throughout the courses as part of their training and assessment activities. These competencies are further enriched by extracurricular activities that complement the education of the students beyond what is established in the curriculum.

In 2022-2, as part of our continuous improvement process, competencies were measured in courses of the last year of the degree program. It was found that the autonomous learning competency, referring to acquiring and applying new knowledge using relevant learning strategies, had a score below expectations, finding that only 50% of the students had a satisfactory level in the indicator "6.2 The student monitors the execution of their learning plans."

For this reason, activities have been developed to strengthen competence in courses at different levels, including the 3rd year where the Communications Theory 1 course is located. At that year, it is proposed that the level of autonomy of the students must be such that, under direction, it chooses an appropriate scheme of work among a set of solution strategies. After selecting the scheme, the student can carry out some activities autonomously.

The course has generated different learning opportunities, the most recent of which involves transferring the course workbook content to a self-executable Matlab notebook based on the live script structure.

[1] https://www.mathworks.com/products/matlab/live-editor.html

This allows the students to manipulate and personally analyze calculation limits and their characteristics. These notebooks are freely downloadable from the course, so they are entirely at their disposal to edit according to their needs. This is in addition to the PUCP agreement with Matlab, which allows students to use all Matlab libraries freely and online.

Based on this material, evaluation opportunities have been created, such as classroom activities based on gamification, self-assessment activities based on the Matlab grader, and a course closing activity developed in the last chapter that incorporates the flipped classroom and the puzzle techniques so that students autonomously create the integrity of the work, forming teams.

Since this is a work in progress, not all changes have been evaluated; there are rubrics for measuring the final work of the course, as well as surveys to assess from the perspective of the user experience of the application of the workbook based in the Maltlab live script and the Matlab grader. Course surveys towards the end of the semester complement this.

Finally, the results will be discussed, and complementary activities will be proposed based on the course experiences and literature review.

II. Designing the Course

A. Literature Review

Although the competence-oriented approach is not new in engineering careers, the methodologies to develop it are diverse, considering approaches such as the one proposed, based on their reiteration throughout the curriculum with a great diversity of activities. Segui and Galiana [3] already proposed a very interesting account of the methodologies for developing generic competencies, and it is clear that in the case of autonomous learning competence, several ones help. One of the most mentioned activities includes reading and discussion from different approaches.

Nagel [4] establishes that the development of competencies relates to how students feel about the activity in which they have participated. If they have more freedom of work or learning through experience, a more significant achievement in related competencies is fulfilled. Another example is how autonomy is achieved through discussion with experts.

Precisely, Arango [5] mentions that "Autonomous learning, from an educational context, refers to the self-directed process that the student carries out in their learning processes, taking the initiative in this process without the need for collaborative help from the teacher" in addition to indicating that the development of digital skills and their use, contributes to the creation of learning opportunities.

On the other hand, in this line of application of self-executing Matlab live script notebooks, a substantial bibliography has been developed in recent years with different applications. In the teaching of science and engineering, it was found that self-executing notebooks are used in physics [6], control [7] [8], signals and systems and vibrations [9], or electrical circuits [10], both as reinforcement for theoretical activities such as laboratory activities [11]. These publications develop the methodology used to build a self-executing notebook; however, the competencies that are developed are not usually measured; the authors usually based their conclusions on the analysis of surveys that show a positive perception of the self-executing notebooks or the Matlab grader as an alternative for formative evaluation.

B. Methodology

In the Communications Theory 1 course, the starting point was the definition of learning outcomes aligned with the competencies developed in the course, including autonomous learning. The learning outcomes of the course are as follows:

• LO1: Explains the characteristics and limitations of analog communication systems based on linear and angular analog modulation techniques.

• LO2: Analyze an analog communication system using spectral analysis tools (in the time and frequency domain).

• LO3: Evaluate the behavior of analog communication systems in the presence of noise or an unwanted situation using power calculations and signal-to-noise ratio based on the search and selection of the required information.

• LO4: Analyze the parameters of analog communication systems and signals, appropriately using the necessary instrumentation and supporting its results.

To continue with the course instructional design, the learning activities of each corresponding session have been defined considering the week of the session, the learning results, the course chapter, the topics of the chapter, the resources or activities, and the evaluation activity.

The following is proposed as a methodology for the first three chapters:

- The professor will teach the course theory classes within the classroom, seeking the participation and motivation of the students with different. Activities developed in the sessions complementary to the script are Kahoot or Menti questionnaires and the Frequency domain charade, where students in groups of 3 represent the signals in the frequency domain with their bodies and movements, verifying that they have internalized time-domain and frequency-domain representations,
- The student will use the self-executing notebook as a reinforcement tool, answering its questions, taking advantage of the proposed Matlab code to deepen their understanding, and validating their learning with the Matlab grader, which provides immediate feedback, ensuring they are on the right track.
- The student will present their questions in the classroom to complement and close the previous class session.

In Chapter 4, the student faces a more significant self-learning challenge since the information no longer comes from a class session but from the videos, offprints, and additional material (which he must obtain), which he must use to learn a specific topic and share their learning with their peers.

The final part of the Communications Theory 1 course mixes all previous knowledge. In the first three chapters, the student learned about signals and systems. Then, the analog modulation techniques were included, and the noise characteristics were discussed. Finally, in the fourth chapter, noise in communication systems is discussed.

In this way, the student, with greater autonomy, uses the materials received and found to build his own learning. He

also prepares materials to share and explain to his classmates, reinforcing his learning process through questions and a summary of the final work. In the final work:

• First, the students form groups and distribute the four communication systems seen, one for each. They are provided with a video explanation, theoretical information in the live script, an additional bibliography, and a forum with questions.

• In class, the new experts gather first to exchange what they have learned in their research and the answers to the forum. In the next session, the groups get together so that each expert can explain to the other group members. Usually, the class can be divided into six or seven groups, allowing the educator to visit everyone and monitor their progress and the materials, questions, and answers they give. Some students have worked on a whiteboard, and others with handouts, slides, and presentations.

• Finally, they make a comparative chart of the techniques, comparing not only what is based on the formulas but also the results of contrasting their understanding of the techniques.

In this way, the student, with greater autonomy, uses the materials received and found to build his own learning. He also prepares materials to share and explain to his classmates, reinforcing his learning process through questions and a summary of the final work.

The role of the self-executing notebook is fundamental, as it allows the student, unlike class notes with which they cannot interact, to reuse the Matlab codes at any time to continue exploring in their continuous learning.

This activity includes an analytical rubric and a single-point rubric to evaluate the panel of experts and the explanation work in groups, allowing us to know through the rubric the mobilization of each student's prior knowledge that has been strengthened with Matlab tools.

III. Implementation

The implementation was carried out as follows:

• Instructional design of the course: The learning outcomes are defined based on the competencies to be developed in the course. These help us build the sessions, starting with motivation activities, reviewing previous topics, developing content with different strategies and in connection with activities for developing generic skills, evaluation activities, and finally, activities to close the session. The development of the activities in the second week of the course is shown below (Fig. 1).

• Previous training activity: The Matlab ONRAMP was proposed as the first laboratory activity, a free online course that explains the basics of Matlab but with the structure of a self-executing notebook made in Matlab live script. The closing document of the activity is the course certificate.

• Development of live script notebooks in Matlab: The creation of one notebook per course unit was defined, so four .mlx files have been developed, which have been structured considering: Introduction, objectives, topic development, code, and elements self-assessment and reinforcement, as is the case with questions, observations, and chapter summary sections. In Annex 1, there are images from different sections of the notebook. However, the live script files and the image bank are in the course folder, with the link in Annex 1.

Week	RA	Topics	Resource/ Activity	Resource Topic	Assessment Activity
2	RA2: Analyze an analog communication system using spectral analysis tools (time and frequency domains)	Signal Analysis, Fourier, Series, Transforms, Properties, Special Functions	Surveys	Recap: Rubric review, forum responses. Main ideas	Kahoot-Communication Systems Quiz
			PPT	Review of Fourier analysis. Fourier series. Fourier transforms	Review of individual tasks - Peer evaluation - Classroom exercise observations
			PPT	Review of special signals in the time and frequency domains. Graphical representation.	Review of individual tasks - Peer evaluation - Classroom exercise observations
			Other		Group activity for signal identification
			Use of Mathematica & Matlab.	Matlab Live Script	Matlab Grader: Individual exercises
L2	RA4: Analyze the parameters of analog communication systems and signals using appropriate instrumentation and providing justification for their results.	Laboratory 2: Introduction to instrumentation	Laboratory		Rubric for laboratory sessions

FIGURE 1- PLAN ACTIVITIES FOR THE SECOND WEEK. (COMPLETE RESULTS IN THE LINK IN ANNEX 1)

• Development of exercises in the Matlab grader: Although this section is not yet fully developed for the course, exercises have already been added in the second and third units, as shown in the image bank.

• Development of the final activity of the course: In this section, in addition to the proposed activities, evaluation rubrics were developed to accompany the process, and surveys were designed to evaluate the integrity of the course process.

IV. Results

These first tables (Tables 1 and 2) partially show the evaluation process results based on the rubric in both sections of the Communications Theory 1 course (sample of 46 students between 2022 and 2023). These tables show that the students achieved good performance in the two stages of the activity. The first consisted of the meeting of experts, where the lowest score was related to problems in communication competence but not in the topic domain. Within the expert session, they were able to complement the missing knowledge thanks to the support and explanation of their colleagues. This allowed a much better performance in the second stage of the final activity, with all students achieving an excellent result according to the proposed analytical rubric. Only in the technique comparison tables did some students not reach the maximum value of the rubric.

TABLE 1-PARTIAL ONE-POINT RUBRIC FOR THE FINAL ACTIVITY. (COMPLETE RESULTS IN THE LINK IN ANNEX 1)

Group	Modulation Technique	Communication (8 points)	Knowledge of the topic by mobilizing the previous chapters (12 points)
2	DSB-LC	7	12
2	DSB-SC	8	12
2	SSB-SC	8	12
2	PM/FM	8	8
3	DSB-LC	8	12
3	PM/FM	8	8
3	PM/FM	8	8
3	SSB-SC	8	12
3	DSB-SC	7	12
4	DSB-SC	8	12
4	PM/FM	4	8
4	SSB-SC	6	12
4	DSB-LC	8	12

Regarding the final activity, the perception of the students was very optimistic since most of them were satisfied with the teamwork, the collaborative learning, the possibility of sharing their ideas, the development of the materials, and the puzzle activity. However, although overall satisfaction is excellent when asking if the puzzle technique should be used in other courses, acceptance declines. The same happens if

you ask them if they learn better in groups. This can be reviewed in Table 3, which corresponds to the final activity. Again, only some of the results are shown.

TABLE 2-ANALYTICAL RUBRIC FOR THE FINAL ACTIVITY. (COMPLETE RESULTS IN THE LINK IN ANNEX 1)

Group	Modulation Technique	Resource Preparation (5 points)	Explanation to Peers (5 points)	Active Listening (2 points)	Response to Questions (3 points)	Preparation of Comparative Summary (5 points)
2	DSB-LC	3	3	2	3	2
2	DSB-SC	3	3	2	3	2
2	SSB-SC	3	3	2	3	2
2	PM/FM	3	3	2	3	2
3	DSB-LC	3	3	2	3	2
3	PM/FM	3	3	2	3	2
3	PM/FM	3	3	2	3	2
3	SSB-SC	3	3	2	3	2
3	DSB-SC	3	3	2	3	2
4	DSB-SC	3	3	2	3	2
4	PM/FM	3	3	2	3	2
4	SSB-SC	3	3	2	3	2
4	DSB-LC	3	3	2	3	2

TABLE 3- PARTIAL SURVEY RESULTS FOR THE FINAL ACTIVITY. (COMPLETE RESULTS IN THE LINK IN ANNEX 1)

#	Question	Agree	Moderately agree	Disagree
P8	Being part of the puzzle activity helped me learn about the proposed topic	78%	24%	0%
P2	I enjoyed the interaction with my colleagues in the expert block	78%	22%	0%
P4	The puzzle activity helped me communicate with my classmates	84%	16%	2%
P7	It is necessary to verify that everyone has seen the videos before interacting with the group	84%	16%	2%
P10	It is important that the work groups are varied	83%	17%	0%
P9	I liked sharing what I learned with my puzzle group	87%	16%	0%
P20	I am satisfied with the themes and materials of the puzzle activity	87%	13%	0%
P13	I learn to listen to my colleagues when I work as a team	85%	13%	0%
P3	I enjoyed the interaction with my classmates in the group stage	89%	11%	0%
P14	It is important to share ideas to achieve the group goal	98%	2%	0%

In the group where the survey was applied (24 students), it was found that they were satisfied with the structure of the sessions, the usefulness of the live script tool, and the supporting questionnaires to a lesser degree but always showed satisfaction with the use from Matlab grader. However, they generally show enormous satisfaction with the materials and activities that have been prepared. The partial results of the survey regarding the opinions of the students on live script and Matlab grader materials are shown in Table 4.

TABLE 4 - PARTIAL SURVEY RESULTS FOR LIVE SCRIPT NOTEBOOK IN MATLAB. (COMPLETE RESULTS IN THE LINK IN ANNEX 1)

#	Question	Agree	Moderately agree	Disagree
Q5	LiveScript is an aid to understanding the course	58%	33%	8%
Q6	The LiveScript must be reviewed before the class session	67%	33%	0%
Q7	Quizzes help verify what you have learned in LifeScript.	79%	17%	4%
Q8	The Matlab Grader exercises reinforce what was learned in LifeScript	58%	33%	8%
Q9	Previous knowledge of Matlab is required to be able to work with LifeScript	42%	54%	4%

An essential element to consider is that students feel these asynchronous activities require three or more hours to conclude. Likewise, when asked about the importance of the laboratory, the response was mostly in favor.

Finally, the results of the student surveys show values above 90% in class preparation, use of tools (graphs, simulation examples, etc.), use of adequate resources for learning, evaluation design, and guidance in classes and assignments. These results are shown in Table 5.

V. FINAL DISCUSSION

The results show that the students are mostly satisfied with the tools developed in the course, such as the Matlab live script notebooks. The rubrics also demonstrate that the knowledge of the course and autonomous learning competence are reinforced with the help of the self-executing notebook. In this sense, students validate this fact by mentioning the importance of the materials developed and their correct design. This is also reflected in student surveys at the end of the semester. The same occurs in previously reviewed publications, such as those from [6], [7], or [9], that obtain similar satisfactory results. However, it is essential to determine that this work contributes to developing autonomous learning competence.

TABLE 5 – PARTIAL RESULTS OF THE COURSE FINAL SURVEY RELATED TO AUTONOMOUS LEARNING COMPETENCE. (COMPLETE RESULTS IN THE LINK IN ANNEX 1)

	Surveyed	
Evaluation criteria (Max 5 points)	Total: 37	%
Prepares his presentation	4,89	98%
Tools, examples, graphics, simulations	4,95	99%
Guides the development of classes and activities	4,77	95%
Effective resources for the learning process	4,64	93%
Evaluations are related with course work	4,43	89%
Communicates the evaluation criteria	4,58	92%

It is also important to highlight that other competencies, such as effective communication, are developed in the process but not discussed in this publication. However, as this is a work in progress, the Matlab grader tools must be improved, as well as the exercises placed in the live script notebooks, given the acceptance of the students.

It must be remembered that not all indicators have been optimal in the process. In the case of the transfer of the puzzle and teamwork experiences, it is clear that the students accept it, but they do not see it as an ideal tool to be applied in other courses of the degree.

VI. CONCLUSIONS AND FUTURE WORK

This work contributes by proposing self-executing Matlab notebooks developed in live script and complemented with Matlab grader to strengthen the knowledge of the students and potential autonomous learning competence. This achievement is validated in the final activity of the course. That takes advantage of what has already been learned in the subject so that students can autonomously develop, thanks to the flipped classroom experience and the puzzle, the final topic of the course. Validation is achieved in the activity evaluation rubric, where students receive an excellent indicator of achievement.

Based on what has been built, it is important to make greater use of the proposed tools and incorporate laboratory activities into the process. This is where SDR devices that can be managed from Matlab itself will be integrated so that students have a comprehensive and autonomous course based on the platform provided by the self-executing notebooks.

The potential of AI must also be considered. The following semester will incorporate activities where students can apply artificial intelligence tools to develop their learning activities. This will allow the course to grow in the diversity of exercises and applications based on the suggestions obtained. It will also involve teaching students how to properly and ethically apply artificial intelligence tools.

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ANNEX 1

First, there is a repository for the live script files, the course design and evaluation Excel file, and an image bank for the final activity photos. The link is: https://drive.google.com/drive/folders/1IkiHzGMo8R2V8M5xoA8DUzaz_JH7SLnK?usp=drive_link

As the entire Matlab files are in the repository of the course, some captures are presented here as reference for the live script notebook sections:

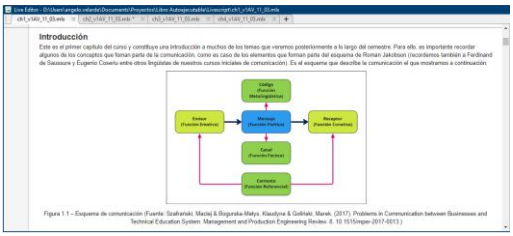

Figure 1 Chapter 1 Live script demo

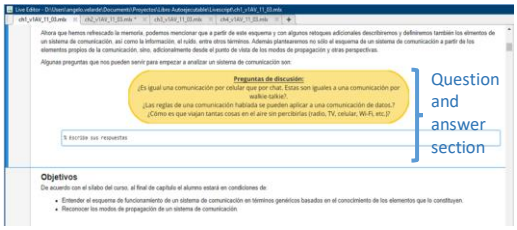

Figure 2-Question Section in a live script

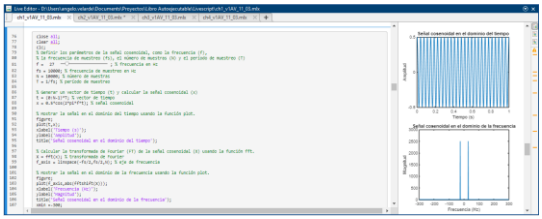

Figure 3-Interactive simulation (cosine time-frequency)

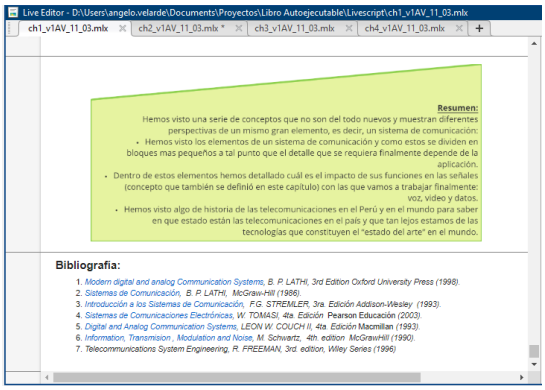

Figure 4-Summary at the end of Chapter 1

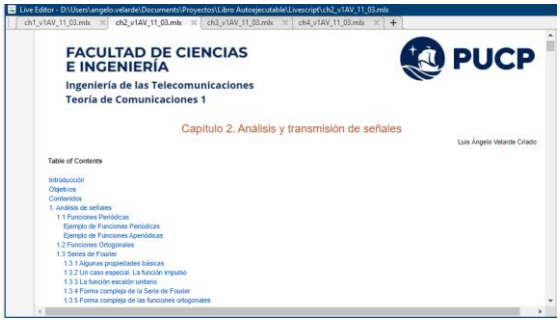

Figure 5-Initial part of the second chapter