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RADIO NAVIGATION AIDS LEARNING, FROM VIRTUAL TO REAL WITH THE KOLB'S EXPERIENTIAL LEARNING CYCLE

Carlos Rubio, Deibi López, Adrián Delgado, Adrián García, Diego Domínguez, & Jesús Gonzalo
Department of Aerospace Engineering, Universidad de León (Spain)

Abstract

Using Kolb's learning cycle provides a structured approach to learning that emphasizes active engagement and application of knowledge. These characteristics make it especially suitable for practical engineering learning. In this study, we describe our enhanced laboratory design dedicated to radio navigation aids in the MSc Aeronautical Engineering program, apply the Kolb's experiential learning model, and evaluate its pedagogical effectiveness. As a conclusion, the learning process is highly reinforced when the laboratory practice includes one live session versus the all-online version, as it is shown in the competence tests where the mean of the qualifications is significantly higher.

Keywords: *Experiential learning, Kolb's learning cycle, navigation aids, laboratory.*

1. Introduction

This study is the continuation of a previous work, presented at the EDULEARN 2021 conference (Rubio et al., 2021), where we tried to improve the learning of Radio Navigation Aids in the MSc Aeronautical Engineering program. Radio signals and spatial modulation are difficult concepts for aeronautical students, as they fall apart from their background usually focused on mechanics and thermo-fluid dynamics. Therefore, we proposed to drive the students to a simulated scenario where they synthesize and analyze the involved radio signals. The effectiveness of this virtual laboratory experience was evaluated by several segmentation, competence, and feedback tests. Despite the fact that the overall performance was satisfactory in terms of technical learning and satisfaction grade, we detected room for improvement in two aspects. First, around half of the students found it difficult to use the programming language needed to create the digital signals. The second problem, which is not specific to this subject but to the whole Master, is that when using virtual laboratories, the students do not have the perception of doing real practices. Moreover, the COVID-related restrictions are now lifted off. Considering the aforementioned aspects, we propose to enhance the practice by adding a final stage with real navigation equipment, eliminating the need to use a programming language, and most important, rethinking the whole process according to the Kolb's experiential learning theory (Kolb, 1984).

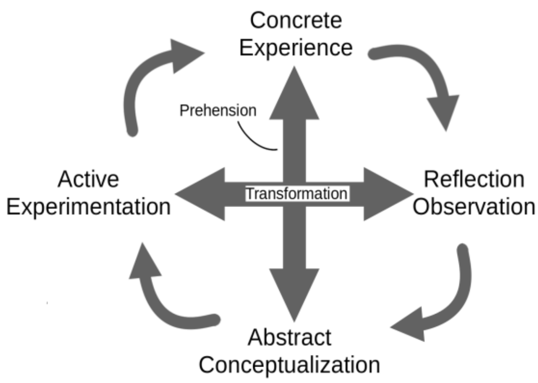
2. Learning methodology

The Kolb's experiential learning theory is one of the most widely used educational theories, although, as any other theory in the field, it has its own detractors and critics (Kayes, 2002). The Kolb's theory uses a constructivist approach where, in Kolb's words: "*Learning is a process, in which knowledge is created through transformation of experience*". This knowledge construction is better performed when the student passes through a four-stage cycle. First, the Concrete Experience (CE) stage, where the student observes and therefore catches information from immediate and concrete experiences. Second, the Reflection Observation (RO) stage, where the student decodes that information and starts to construct a mental map of the subject. Third, the Abstract Conceptualization (AC) stage, where the student, by means of inductive reasoning, is able to develop new abstract concepts and generalizations. And finally, the Active Experimentation (AE) stage where the student applies the learned concepts in new situations to contrast and expand his knowledge. Stages one and three correspond to the prehension axis, where new information is grasped. On the other hand, stages two and four conform the transformation axis, where the acquired information is consolidated, rejected, or transformed. Previous models, like Piaget's model (Piaget, 1978), give more importance to certain stages of the process, but Kolb and later authors like

David, Wyrick, and Hilsen (2002) state the importance of providing balanced learning using the four stages of the cycle.

In our proposal, the students perform a practice that comprises two parts. The first is a virtual laboratory phase where the students generate and test the signals corresponding to a Very High Frequency Omnidirectional Range (VOR) and an Instrument Landing System (ILS). VOR is a radio navigation system that provides directional information to pilots, while ILS is a precision approach system that guides aircraft to the runway centerline and correct vertical height during landing. In the previous version, the students recreated the signal using the SciPy library ("SciPy", 2023) and the Python programming language ("Python Software Foundation", 2023). To avoid the difficulties around using the programming language, in this new version we changed to the GNU-Radio ("GNU Radio project", 2023) software that allows creating the signals using only block diagrams. In order to increase the feeling of doing real practices and to intensify the knowledge-construction process according to the Kolb's theory, we added a second part where the students check its designs with real navigation equipment. The fit of the overall process in the Kolb's theory can be viewed at two levels in a fractal way. One inner level where the first part of the practice goes through all the Kolb's stages, and another outer level where the first part act as the first three stages of the cycle and the real laboratory part corresponds to the fourth stage.

Figure 1. Kolb's Experiential Learning Cycle.



The first implemented Kolb's cycle, the inner cycle, corresponds to the virtual laboratory. It starts in the Concrete Experience phase, but some prior knowledge is assumed as the students must previously have studied the subject Radiometry of Navigation Systems. In this Concrete Experience phase, the professor demonstrates step by step how to create the GNU-Radio diagrams for the basic radio modules (AM modulator, FM modulator, up-converter, filters, etc.) and requests the students to do it by themselves. For the second stage, Reflective Observation, we perform a questionary with the twofold intention of verifying assumed previous knowledge and stimulating the reflective reasoning in the construction of the radio diagrams. The third stage, Abstract Conceptualization, corresponds to the principal task that consists of designing the complete diagrams for the VOR and the ILS. The students should be able to generalize and connect the individual concepts with minimum guidance from the professor. The outcome of this phase is the input for the subsequent, Active Experimentation, where the students verify its implementation using virtual instrumentation.

The second Kolb's cycle, the outer cycle, assumes that the previous part of the practice covers the CE, RO, and AC phases. Once finalized the first part, the students had constructed the knowledge that conforms the prehension axis of the outer cycle. This strategy of using a virtual laboratory to develop the prehension axis and leaving for the real laboratory only the Active Experimentation phase is also found in other similar works like (Abdulwahed & Nagy, 2009). By maximizing the use of virtual laboratories, this scheme optimizes the utilization of the physical laboratory, which typically has limited availability due to tight time constraints. The first part, without time restrictions, allows enough variation and repetition to consolidate the knowledge (Kirschner, 1988) in contrast to the single demonstration scheme used typically in real laboratories.

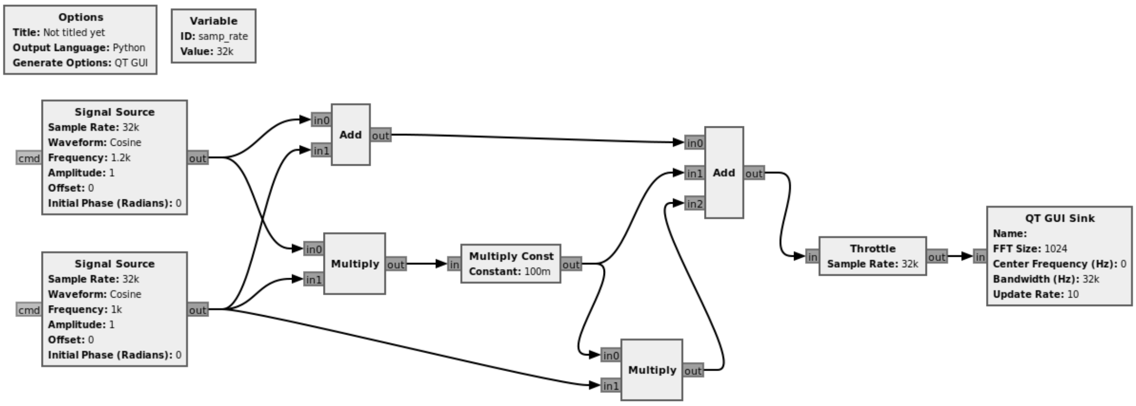
3. Laboratory description

The laboratory can be divided into the virtual laboratory part, used for the first Kolb's cycle and the physical laboratory, used in the final phase of the second cycle.

3.1. Virtual laboratory

The virtual laboratory is based on the GNU-Radio software. GNU-Radio is an open-source package for signal processing and Software Defined Radio (SDR) management. It provides implementations of many signal-processing algorithms as reusable blocks. These blocks are configured and connected in diagrams, as shown in Figure 2.

Figure 2. GNU-Radio intermodulation example.

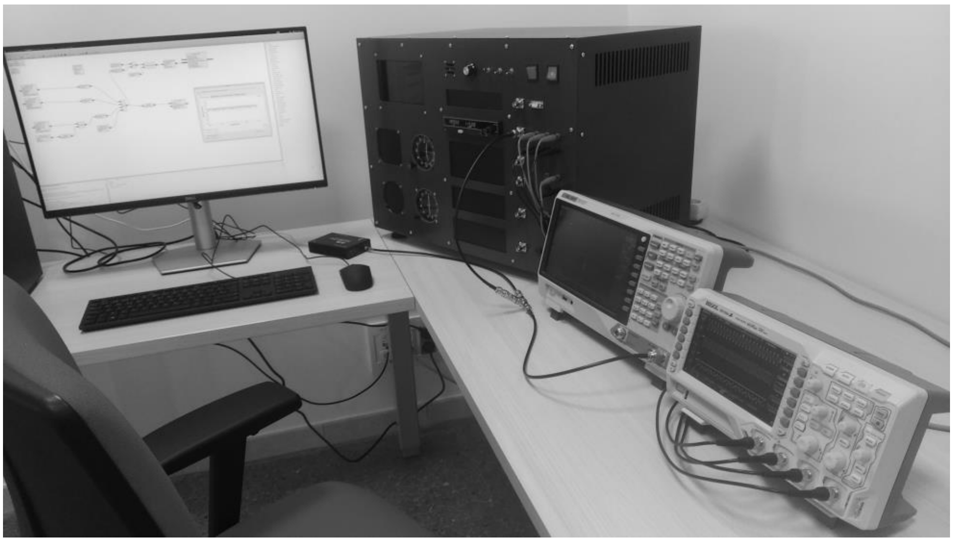


Along with the signal generation and processing blocks, GNU-Radio also includes instrumentation blocks that can be used to check, measure, and represent the signal characteristics in the time or in the frequency domain. The students use those instrumentation blocks to check their designs and analyze the effects of variations in the block diagrams. Hence, these tools are particularly useful in developing the transformation axis of the Kolb's cycle, especially in the extension extreme. The software is easy to install on any personal computer (PC), allowing the students to perform this part of the practice on their own PCs without time constraints.

3.2. Physical laboratory

The laboratory equipment allows to synthesize the radio signal from the student's GNU-Radio diagrams. It comprises a Linux computer, a software defined radio (HackRF One), a navigation receiver (Bendix-King KN53), a VOR/ILS indicator (Bendix-King KI203), an oscilloscope (Rigol DS1054Z), a spectrum analyzer (Siglent SSA3021X), and a panel deck with test plugs connected to the instrument's internal signals. The design philosophy is to make its use as simple as possible. Moreover, the professor assists in handling the oscilloscope and the spectrum analyzer during the session. Otherwise, the limited amount of time per student in the physical laboratory is dedicated to learning instrumentation details or following step-by-step instructions instead of interacting and reflecting on the VOR/ILS concepts.

Figure 3. Laboratory setup.

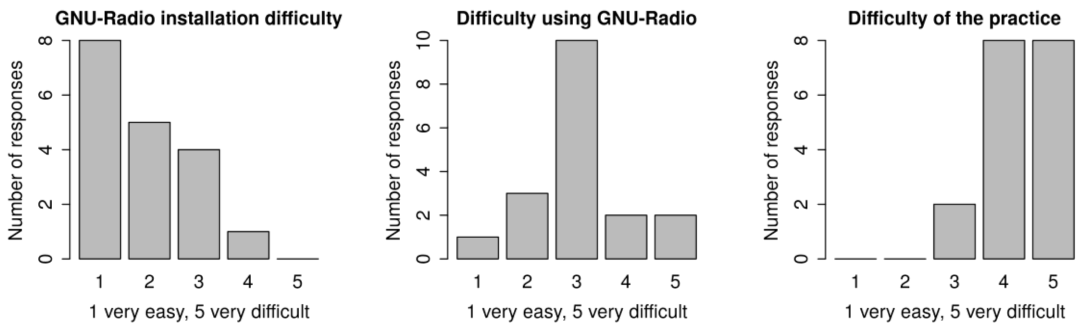


4. Pedagogical effectiveness evaluation

The pedagogical effectiveness of the enhanced practice was evaluated by several competence tests. The evaluation process starts with a first competence test to assess their previous knowledge. After teaching the theory and finishing the Concrete Experience phase of the inner cycle, the students repeat the competence test and respond to additional questions that stimulate the Reflection Observation stage. Next, they perform the practice and submit their assignments. When the assignment's due date expires, they repeat the competence test to measure the overall progress and fill out a final questionnaire to appraise the practice and express their opinions. As part of the students is following the course online, the students are divided into two groups by making the physical laboratory part optional. In this way, the differences related to learning are evaluated between the students who only performed the inner cycle and those who performed both cycles.

One target of the enhanced practice was to avoid the difficulties around using a programming language. The students evaluated the difficulty of installing the GNU-Radio software as low and the difficulty of using it as medium (Figure 4). In contrast, in the previous practice design, the results showed a bi-modal distribution, with half of the students considering using Python easy and half considering it difficult.

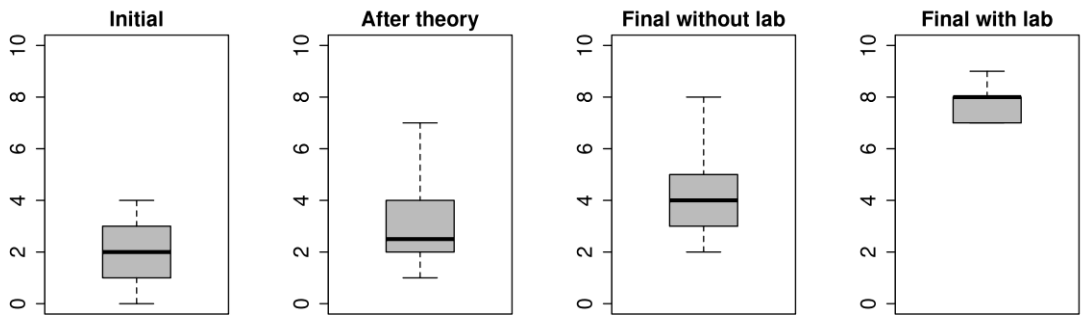
Figure 4. Difficulty assessment.



Although the target of avoiding difficulties using the technology was successful, the students still considered the whole practice hard or very hard (with a score of 4.33 on a scale from 1 to 5, similar to the score of 4.5 in the previous design). The students reported complications and a lack of guidance on how to combine the canonical blocks into a completely functional design. This part corresponds to the Abstract Conceptualization stage of the inner cycle. We consider this stage a key part of the whole practice, as it requires a solid understanding of the individual concepts and the overall picture. This process requires hard work and effort, as students must revisit their previous knowledge, actively seek new information and infer how to obtain the desired navigation signals. Without this effort, knowledge remains superficial and disconnected, lacking the deep understanding and integration that comes from active engagement. On the other side, going through this process can generate frustration in students, as some reported in the satisfaction test. One way for students to mitigate this frustration is through the final practice in the laboratory, where they can fix their own mistakes. Students who did not participate in laboratory practice are provided with a tutorial class explaining the final solution.

The successive competence tests, which results are represented in Figure 5, show significant learning, particularly for students who participated in the final laboratory practice. In the initial competence test participated 22 students while in the subsequent tests participated 18. The students started with a mean knowledge level of 2 over 10. Once the theoretical lessons are explained, the mean knowledge level increased to a mean value of 2.8. The final score was 4.3 for the students without the second cycle and 7.8 for those who performed the whole practice. The competence test was intentionally designed to be difficult, including some tricky questions. Even without the final laboratory practice, a clear progression in learning is noticeable, but the remarkable improvement occurs when performing the whole practice. The superior learning outcomes achieved through laboratory practice justify its inclusion and allow us to validate the proposed enhanced design.

Figure 5. Competence tests.



5. Conclusions

In summary, we have applied Kolb's experiential learning theory to a practical case in engineering studies, designing a laboratory that minimizes difficulties related to non-essential knowledge and allows students to focus on VOR and ILS concepts. By separating the learning into two cycles, we achieved greater learning and maximized the utility of the real laboratory. The pedagogical evaluation has demonstrated an increasing degree of learning through the competence tests at different stages, particularly for students who completed both cycles, although the practice was considered challenging, especially in the Abstract Conceptualization stage. Particularly, students who completed both cycles reached significantly higher qualifications than those who did not. As a final conclusion, separating the learning into two cycles achieves a greater learning and maximize the usage of the limited laboratory assets. Furthermore, it is possible to infer that using only virtual methodologies should be avoided (at least in engineering and technical courses) to maximize learning outcomes.

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