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Structuring knowledge as a strategy and tool for learning and evaluation in engineering education

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Abstract

In this proposal, the evaluation activities together with the structuring of knowledge in conceptual maps are considered as dynamic elements to promote the gradual development of a higher level of understanding. The results achieved in this formative experience show us that the use of evaluation and feedback as part of the formative process, and not only as an appendix of measurement, allows students to adjust their training actions to meet course requirements

Keywords: *Structuring knowledge; Hibrid teaching context; SOLO taxonomy; engineering education.*

1. Introduction

As teachers and students, especially in technology-related professions, we face an overwhelming amount of information, which, day by day, increases exponentially. In this context, a teaching oriented to the transmission and coverage of content is an option that promotes the feeling of stress, but, above all, with the ease of access to information, it does not help students learn to manage and take advantage of that knowledge. This does not imply that it is not necessary to base our study on solid knowledge bases; rather, the opposite is true. We need to establish what are the fundamental concepts and their structures of relationship, so, from a broad perspective, approach the deep knowledge of this subject and transfer it to new contexts, outside the reality of the classroom. That is, the capacities of analysis, reflection, generalization and discernment are an integral part of learning to learn.

From this perspective, we can see that learning is not the sole responsibility of the student, but also of the teacher, his conceptualizations and his ways of teaching. Teaching and learning are not two independent processes, but, on the contrary, they are correlated, with two-way influence from each other. For example, several authors state that how teachers evaluate their students provides the direction in which students will orient their activities to reach the level of understanding required to pass the course (Biggs and Collis, 2014; Biggs,2014). From this perspective, we as teachers need to be clear and precise about what it means that something or subject of our course has been learned, and give students the key indicators so they can be aware that they are on the right path to mastering that knowledge. It is clear, from this vision, that evaluation turns out to be a fundamental part of the teaching and learning process; not only to decide if a student has reached the required level, but as an instrument of teaching, guidance, feedback and motivation (Henderson et al., 2019; O'Lynn, 2021). For this purpose, continuous questioning, based on key questions (McTighe & Wiggins, 2013) that motivate reflection, from the teacher and from the students themselves, together with adequate feedback are significant to achieve the expected learning outcomes.

In this article, we present a teaching and learning experience, in small groups and in a hybrid environment (face-to-face and virtual), which focuses on those two key aspects discussed in the previous paragraphs: structuring knowledge and assessment as strategies and tools to stimulate deep learning in engineering students. On the one hand, conceptual networks were used, structured from the vision of threshold concepts and students' notes, as elements of study, along with the use of key questions during class sessions to guide students at the desired depth level. On the other hand, the evaluation, as an essential element of the learning process, consisted of two phases: one of probing and feedback of the levels of understanding reached by the students and the other of scoring and final assessment.

This article is organized as follows. Section 2 presents a brief review of work related to pedagogical proposals based on learning outcomes and threshold concepts. Then, in

Section 3, the teaching and learning experience develops is briefly described. Finally, Section 4 concludes the paper and points out some lines of future work.

2. Background

2.1. Understanding and deep learning

In the literature, we find several works that address the problem of individual variations in academic understanding presented by students. For example, Biggs (2014) proposes so-called learning outcomes, which start from the determination of different levels of understanding. These levels are based on the internal structure and relationships of the different concepts considered in the answers that students present to the questions proposed by the teacher. Therefore, these authors propose five levels of understanding: pre-structural (with material not relevant to the topic), unistructured (where a single aspect of the theme is included), multistructural (where various aspects of the subject are included, but without showing existing relationships), relational (various aspects are shown with their interrelationships, but always from the material addressed in class), and abstract extended (where a generalization and theorization is presented). In that same order of ideas, but including an additional level related to emotional and motivational dimensions, Entwistle (2018) raises six levels: mentioning (with inconsistent pieces of information), describing (showing extensive descriptions of the topics treated in class or from the books), relating (with explanations from various sources, but without greater support), explaining (with the use of relevant evidence to support explanations in a logical and structured way)conceiving (with the development of individual conceptions based on individual reflection and showing a broad understanding of the discipline), and expansive awareness (with the reinterpretation of the understandings reached to be extended to new contexts, with a personal involvement with the phenomenon, rather than a theoretical distancing in the interpretations).

In both cases, since the proposal of Biggs and Entwostle, the first three levels refer to superficial learning, which highlights the lack of structure in the knowledge acquired and without showing the existing relationships between the different concepts that are part of the discipline under study. On the contrary, the higher levels (from the fourth onwards) can be conceived as a form of deep learning. One of the main characteristics that is appreciated is the existence of a coherent and relational structure of the different nodes that form this knowledge, and even producing a transfer to new contexts and the reconstruction of those learnings from a more emotional and personal perspective.

2.2. Assessment and feedback as learning tools

In the tradition of instructional design, assessment has been relegated to the final stage, as a level of measurement of student achievement and, in many cases, the effectiveness of the teaching process applied by teachers. However, several authors have highlighted the importance of assessment as an integral part of the learning process and not just as a measurement appendix. For example, in the case of the backward design (Wiggins et al.,2005), in which the desired results together with the instruments to be measured are the starting point of the design of the entire instruction process. On the other hand, Biggs (2014) proposes the concept of aligned constructivism, which mixes the conceptualization of constructivism, as the construction of knowledge in the mental structures of each individual, and the curricular theory of alignment, which states that assessment tasks should be aligned with desired learning outcomes. As we can see in both proposals, evaluation becomes central in the design of teaching. However, Biggs' proposal, unlike the reverse design, visualizes the assessment as part of the student’s learning path. In this way, the student builds knowledge guided by the awareness of what level of understanding is expected of him/her and stimulated by learning activities that, sequentially, lead him to the achievement of those results.

In the literature, two types of assessments can be seen: summative and formative, together with formative feedback (Henderson, 2019). The first refers to all those evaluation activities that lead to the attainment of some grade that is used to judge the degree of approximation of the student to the expected performance. On the other hand, formative evaluation leads to the generation of some type of feedback for the student, which does not lead to a degree used for the subsequent judgment of the student’s performance. A completely related aspect is the formative feedback, which refers to some type of information, process or activity that allows students to stimulate learning based on the comments given to the formative or summative assessment activities.

In this sense, the proposal presented in this paper is based on the design of an evaluation process that is summative and formative, simultaneously. This allows the student to improve their initial grade (summative) through a following reflective process, where the feedback the teacher offers allows them to deepen their learning to reach the desired level in a second evaluative meeting with the teacher.

3. Context of study

In this article, we present an experience of teaching and learning carried out in the subject of Wireless Communications, belonging to the eighth semester, in the degree of Telecommunications Engineering of the Universidad Politécnica Salesiana (Cuenca, Ecuador), during the months of September 2021 to January 2022. Due to the restrictions resulting from the Covid-19 pandemic, the university developed its academic activities in the hybrid modality, so that students could attend classes in person or online, through the platform used for this purpose, so that both students in the classroom and those connected through the telematics platform could interact with the teacher and the exposed content.

For the experience we presented, the course consisted of 20 students, of which 5 students participated in face-to-face, while the remaining number of students opted for the virtual modality. The Wireless Communications course consists of four units.

3.1. Learning process and assessment and feedback activities.

Figure 1 shows the main training activities and processes carried out in the course to achieve the proposed learning outcomes (without considering the activities carried out in the laboratory). The formative process begins with the design and planning of the course, which is based on a collaborative teaching through the Teaching Cloister of Telematics and Telecommunications (an organizational structure of teachers of a specific knowledge area for the development of training and research processes). In this first phase, we establish the expected learning outcomes, proposed according to the SOLO taxonomy (Structure of Observed Learning Outcome) (Biggs and Collis, 2014), the evaluation tools to be used, and share the best methodological practices used so far among the members of the cloister. With these inputs, the teacher proceeds to the planning of his academic activities.

Already in the execution of the developed planning, lectures with teacher-student interaction constitute the moments in which the teacher describes and deepens the analysis of the main concepts and the existing relationships between them, which will allow the student to have a complete vision of the subject under study. Our vision of learning (see Section 2) leads us to the need for the student to structure his knowledge in such a way that he can appreciate the fundamental concepts studied, their interrelationships and possible generalizations of the knowledge reached to other aspects in the field of telecommunications engineering. To achieve this, we rely on three tools: essential questions, study notes and mind maps. Note that, throughout this process, the expected learning outcomes are the main inputs that feed all the formative and evaluative actions.

Our expectation was that students, according to taxonomy SOLO, reach at least a relational level. For this, as part of the feedback process, during the lectures, essential questions were asked to encourage students to contrast and relate the information provided with that studied in the current unit or in previous units, and even, compared to other courses that had been taken by students in the previous semesters. For better orientation of students in their learning and to avoid uncertainty in the process and assessment activities, in the first class session, and at the beginning of each unit, students were informed of the evaluation rubric with the expected results along with the possible scores for each of the levels.

One of the issues that we considered as fundamental to achieve that students reach the levels of learning and the skills required was the need to generate learning routines that allow them to generate and exercise the ability to recognize and extract the fundamental concepts of the subject under study, their relationships and possible applications in other fields outside of those analyzed in class. To do this, we take advantage of the study notes that are typically generated by the students and which became part of the activities requested for summative evaluation. These class notes should not be a transcription of the slides and notes of the teacher offered as part of the resources provided in the course, but should make explicit the work of extraction and deepening in each of the concepts, characteristics and possible relationships. At this point, the essential questions posed in the classes constituted a first orientation of the teacher towards the expected level of knowledge structuring, allowing students to expand or reorganize their notes.

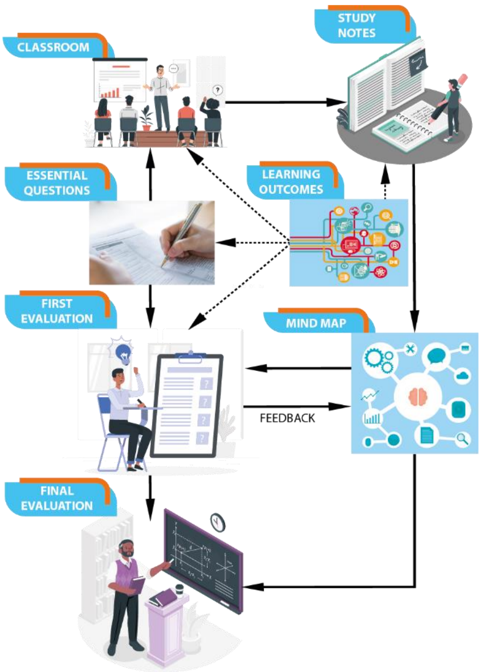

Figure 1: Flow chart of the evaluation and feedback process.

Following this line of action, another evaluation activity constituted the formulation of mental maps, in each of the topics addressed. This material was the only one that could be used by students in the synchronous evaluation process with the teacher. The use of these graphs was intended to enable students to generate an overall view of the structure of the fundamental concepts, existing relationships and awaken in them the awareness of the underlying difficulties in understanding certain concepts and their importance for the level of understanding achieved.

For each of the units, two 60-minute sessions were allocated for the evaluation, with the participation of two teachers of teaching staff. The first session, in which the students received a score according to the level reached, consisted of an individual interview, virtual or face-to-face, according to the modality chosen by the students, with a maximum duration of 20 min. Based on questions asked by the teacher, the student, with the support of the mind maps generated, proceeded to develop his answer. The response needed to be concise and thorough in its analysis. This first meeting allowed teachers, beyond scoring the level of understanding reached by the student, to offer feedback. The student, if desired, could improve the grade obtained, from the comments offered by the teacher.

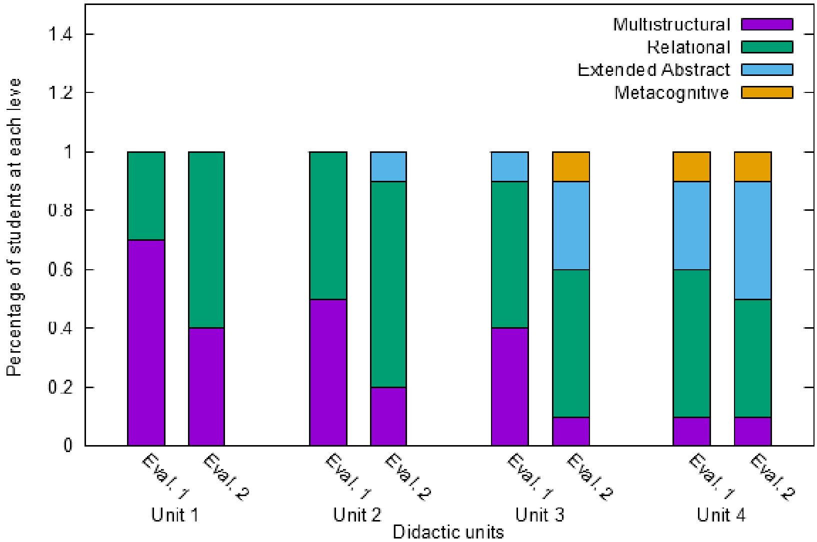

Figure 2: Assessment results for each didactic unit according to SOLO taxonomy.

3.2. Results and discussion.

Figure 2 shows the results of the assessments of the students. In general, an evolution is observed from the level of understanding shown in unit 1, with a majority presence of a multistructural performance to reach relational levels and extended abstraction and even metacognitive, in unit 4. Thus, we observed that in unit 1, the initial level shown in the first evaluative meeting was mostly of a multistructural level; however, in the second evaluation, after the feedback processes, both at the level of mind maps and the responses proposed in the initial interview, many of the students managed to improve their performance reaching the relational level. We observed that, in this unit, no performance was achieved in the responses of students tending to generalization and metacognitive analysis. One of the possible causes for this was the fact that, according to feedback from students, this was the first time they were evaluated in that format, so, despite knowing the expected learning outcomes, they did not focus on improving their level of understanding. Another of the difficulties shown is that, being the first unit, which has a wide mathematical content and without a broader vision of its application already in the technological field, students failed to visualize possible applications in the field of study.

This situation was improved in the following units. For example, in unit 2, we observed that the level of relational understanding was reaching greater presence in the response of the students, and even, in the second evaluation of this unit, you can already see that several students show answers with an abstract extended level. Moreover, in units 3 and 4 we can already see that most students have passed the multistructural level and have achieved deep learning, and even some of them have reached the metacognitive level. This may be because, while the final units have a higher level of complexity; however, they are designed to integrate and leverage the knowledge studied in the previous units and, in addition, it allows students to relate this knowledge to existing technological advances and the possibilities of development that are coming. On the other hand, we could see in the quality of the notes and the mental maps developed, that the students, mostly, adapted their performance and form of study to the demands of the new evaluation process, which allowed them to gain learning routines and thus develop the skills needed to reach the required levels of understanding.

4. Conclusions

In this article we have presented a teaching-learning experience for engineering students in hybrid modality (face-to-face and online simultaneously), in which, from the expected learning results, following the taxonomy, and based on the structuring of knowledge and feedback processes, evaluation activities were designed to be an active part of the student's learning process. The results achieved in this experience show us that achieving higher levels of understanding requires students to establish learning routines, so that, gradually, adapt their study style to the new assessment and approval requirements dictated by the teacher.

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