

**article:2217**

## **Conceptual Maps: Measuring Learning Processes of Engineering Students Concerning Sustainable Development**

Engineering education programs in Europe are introducing new courses on Sustainable Development (SD) and Sustainable Technologies. This paper evaluates what students learn in this type of courses whose core is usually based on ethics, holistic science, critical thinking and the role of technology in society. Two main research questions that guide our work are:

The first one is “What do engineering students learn on sustainability related courses?” And also related to this question, “Which is the starting level of knowledge and assumptions on SD of engineering students?” These questions arise from studies that point out the difficulty to learn sustainability concepts in engineering courses. The main aim is to improve the evaluated courses by evaluating how much the non-engineering knowledge of sustainability is learned by students.

The second question is: Which is the optimal way of teaching SD to engineering students? Conceptual maps (Cmap) are used to evaluate the knowledge acquired by students. The use of conceptual maps in education research is widely spread since concept mapping stimulates learners to articulate and externalise the actual state of their knowledge.

In this work concept mapping is applied to evaluate the knowledge acquired by over 700 engineering students, from different European Technological Universities, who took specific courses on SD. The student sample has been taken from 6 courses on SD. On the one hand, the results obtained allow to evaluate the students’ initial knowledge on SD and to identify their misunderstandings and gaps – which is very useful information to improve the courses. On the other hand, the changes produced by the courses in the students understanding of Sustainability can also be evaluated from the obtained results.

The methodology consists in asking students to draw a Cmap which describes the concepts related to sustainability and establishes the links between them. No concepts are given other than the initial concept of sustainability, and students are free to use any concept they think is relevant. The exercise is done at the beginning and at the end of the course and, each time, students are given 15 minutes to draw the Cmap.

In order to evaluate the Cmaps concepts are clustered (classified?) in categories and evaluated according to two indicators. The first one is the Category relevance indicator which evaluates the percentage distribution of the concepts among the categories which reveals the width understanding of the concept Sustainability. The second one is the Complexity Indicator which analyses the interrelations between the categories and measures the complexity associated to sustainability.

The analysis of the results shows that when teaching SD to engineering students it is important to emphasise the social and institutional aspects, as well as the “soft” knowledge related to sustainability. Indeed, the students’ initial conception is that sustainability is mainly linked to environmental and technological aspects. Moreover, the courses did not seem to succeed in highlighting the importance of the social side since especially the categories of Ethical, Unbalances and Future generations still have low rates on the maps drawn at the end of the courses. An additional conclusion is that the role that technology plays on sustainability has to be redefined in order to enhance the challenge of avoiding and solving environmental problems instead of being their source/cause.

The main result of the study is that the image students have of Sustainability becomes substantially more complex. Thus this result shows that the main learning outcome of the current SD courses is the capacity to connect concepts in a system perspective more than to identify these concepts in a more balanced way among the categories.

Comparing the results obtained in the Cmap analysis from different courses, it is difficult to see any trend directly associated to the pedagogy used in each course. More research is being conducted in order to identify the relationship between the teaching method and the obtained results.

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