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DESIGN OF PEDAGOGIC TOOLS FOR TEACHING MATERIALS IN PRODUCT DESIGN ENGINEERING

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ABSTRACT
The education in materials constitutes a vital part of the education of an engineer, since its comprehension determines the design and construction of products with appropriate materials that satisfy the current and future needs of the 21st century society [1]. In the Product Design Engineering degree, teaching and learning the attributes and applications of materials shouldn't be limited to lectures. This paper shows how through the design of pedagogic tools it is possible to go from a knowledge-transfer method to a student-centred method where motivation, teaching and learning strategies and problem-based learning, support meaningful learning [2] through the implementation of these tools in the classroom.

Keywords: Learning strategies, pedagogic tools, competences, materials, design.

1 INTRODUCTION

Nowadays, teaching and learning in materials constitutes a challenge: integrating materials science with the needs related to engineering and design demands teaching methods that allow the professional to assume a more global vision in order to meet the needs of society [1]. Mike Ashby has done a significant contribution by developing books with different approaches to the ones found in traditional books of materials science, and are accompanied by the *CES Edupack* [3] software to manage information. Spaces like *Matter FAD* [4], *Material Connexion* [5] and the design fairs have changed the way to access the information on materials and the promotion generated by these organizations helps designers to be updated and face the changes in the material world. However, understanding the basic information about the attributes of materials, such as their magnitudes, concepts and meanings in a technical specifications sheet, demands from the student experience and learning beyond having read engineering books or listened to a lecture. The contribution to teaching and learning in materials made by Universidad EAFIT lies in the development of pedagogic tools that aim at increasing students' motivation, promoting meaningful learning of the contents of the subject, and supporting the role of the teacher as a coach and not as the centre of attention. These remove -Power point- and teachers' lecturing as the only teaching strategies, and replace them with new ones that can be more useful to learning and promote the competence in the PDE profile.

2 METHODOLOGY

The design of the pedagogic tools was part of a sabbatical semester 2014-02. For their development the following stages were followed:

Phase 1: the first step was to diagnose education in materials globally and locally. Then, the pedagogic model of Universidad EAFIT, which promulgates a student-centred model, was reviewed, and then concepts related to pedagogic tools were examined, articulating them around the aforementioned model. Figure 1 summarizes these steps. It was taken into account that the previous model of the subject had the teacher and lectures as the centre; in the new model, the student is the centre of the process and the teacher acts as a coach. The teacher designs the learning environment in the classroom using several resources, so that through motivation, encouragement and development of problems, meaningful learning of basic topics of materials science takes place.

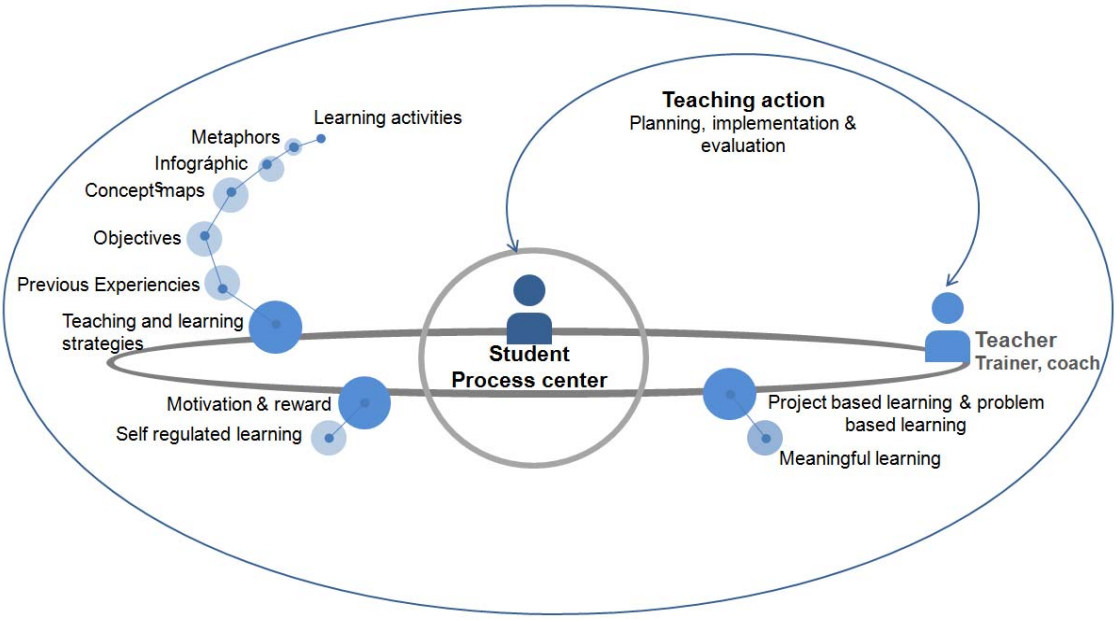

Figure 1. Pedagogic model to be developed for the subject "Materials in design"

Phase 2: for the development of the previous model, the starting point was an input-output scheme as the basic outline to design the course, taking into account the previous knowledge, the competences to achieve in the student and the field of development which enables the student to go from point A to point B. The field of development is the place where all the strategies for the course, which constitute the core of the project, will emerge. See Figure 2.

The *previous experiences* [6] comprise the experimentation with materials in other subjects where design projects have been developed, the representation of different materials and textures through drawings, and engineering knowledge from subjects such as physics or chemistry. Regarding the competences expected there is a consideration of competences from knowledge, know-how and attitudes.

In relation to *what students must know,* several aspects are taken into account: recognize the different families of materials understand the technical and sensory attributes, comprehend why some materials are used in certain products, and use materials to solve problems in the design process. To answer the question of *what type of know-how students need,* skills such as identifying possible materials for their projects according to the restrictions of a brief, knowing where to find and how to interpret information about materials to use it appropriately when designing. Finally, *the attitudes students should have* are motivation, curiosity and a permanent disposition to learn about materials, decision-making and problem-solving abilities, and creativity to solver situations innovatively. [7]

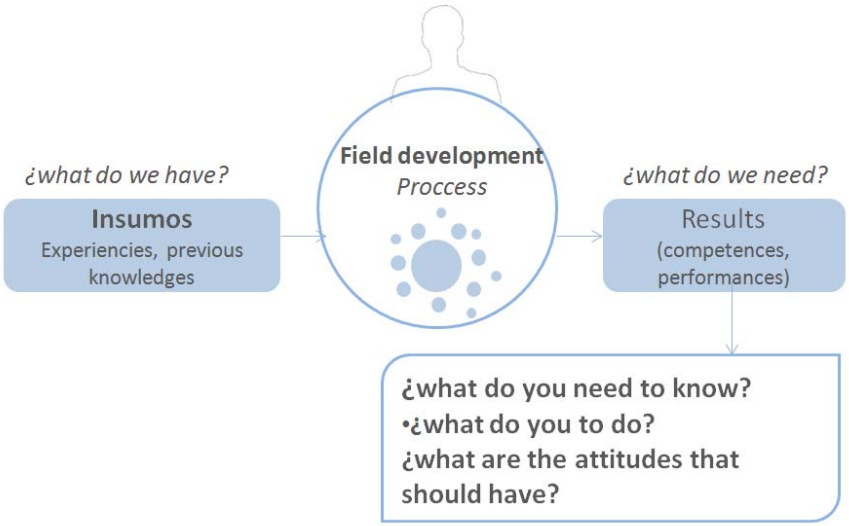

Figure 2. Field of development to design the course "Materials in design"

Phase 3: from this plan, the product design process was adopted as a model for the initial process to design the subject *Materials in design* in six stages: problem definition, generation of the concept, embodiment, detail design, production and implementation. After each stage, came the development of four transversal models based on the MISA method, -engineering learning systems method- which was adopted for this project.

- Knowledge model: what competences must the model develop and who is it aimed to?
- Model based on pedagogic tools: how will the competences be developed and what is the strategy that follows?
- Resources model: what materials are needed for the task?
- Course management model: what are the roles of the teacher and the student in this model?

This process is presented in Figure 3.

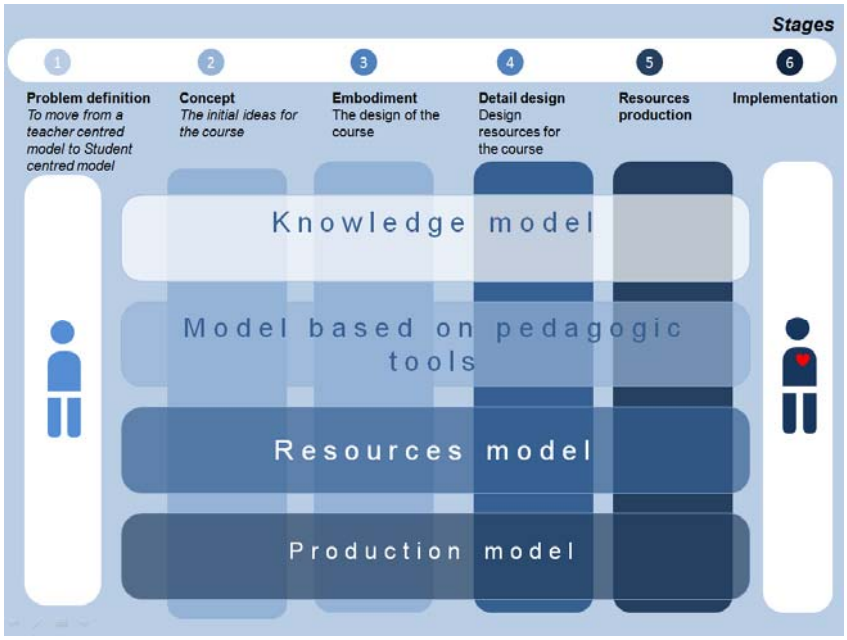

Figure 3. Teaching in materials model for Materials in Design in PDE

With the development of this model, it was possible to clarify what pedagogic tools were necessary for the six units that comprise the subject, namely: the role of materials in the discipline of design, attributes of materials, metals, ceramic and glass, polymers and compound materials.
Phase 4: pedagogic tools for each unit of the subject were created according to the competences expected from students. In each unit, the tools seek that the teacher acts as a coach that accompanies the student who, in turn, tries to regulate his own learning process. These tools are described in Figure 4.

Figure 4. Pedagogic tools for the subject Materials in design

For example, unit 2, *Material's Attributes*, a magazine with infographics called *"Material's Attributes"* is used. This resource connects the properties of materials with comics' superheroes. See Figure 5. Each page describes an attribute, why it is important to understand it, how it is measured and units employed, and finally, the reasons why materials can fail in use conditions in relation to the attribute detailed. Students read the magazine in the classroom, discuss, and, at their own pace, make questions about information that needs clarification; the teacher guides the process and strengthens concepts with other pedagogic tools. In this case, for example, he uses a materials box with samples and objects that help to explain phenomena of the materials, for instance: using a rubber band to explain the concepts of strength and deformation, or using a *Nitinol* wire to explain thermal expansion. At the end, comes the *Materioteca* –a library of materials in partnership with *Material Connexion*- to analyze the sensory attributes of materials and students complete an assessment activity which involves choosing a product, comparing its attributes, understanding why is made of that material and analyzing values and magnitudes.

In the case of unit 3, the project created four different videos supported in motion graphics with the objective of introducing the topic of metals and accompanied by concept maps and index cards that explain the relationship between the microstructure of materials, their attributes and applications.
For unit 4, infographics are used as an assessment activity and concept maps as pedagogic tools to introduce the topic of ceramic and glass. The topic Polymers is supported in videos, molecular models, the material box and an educational game to explain the divisions between the main families of polymers called "*Polimeria*". Finally, the unit on compound materials is organized with an open seminar where two teachers share their experience and knowledge in front of the class and encourage students to make questions about the topic.

Figure 5. Using infographics as a pedagogic tool in the classroom

Phase 5: for each unit of the course, a work guide for the teacher was designed where he can find the competences to be developed, the time for the activities, the setting (outdoors or indoors), a description of the tools, how to use them and what is their contribution to learning. In addition, there are references for the learning and evaluation activities, presentations and bibliography. The design of these guides is shown in Figure 6.

Figure 6. Work guide for teachers of the subject "Materials in design"

3 RESULTS

Currently, the course *Materials in design* of the fourth semester is using the pedagogic tools (2015-01). The project is now in a validation stage, which will be carried out with an academic peer who is teaching the same content with a traditional pedagogic model. Once the semester ends the results will be compared quantitatively and qualitatively to verify the effectiveness of the new learning model described in this project. As to this day, some positive effects in the classroom have been observed:

- Higher motivation in students: there is a perception of higher understanding of the concepts studied because of the implementation of the pedagogic tools, or what Woolfolk defines as "intellectual achievements".
- An increase in students' participation: the teacher guides the activities and the students read, ask, analyze and understand information –previously only the teacher talked.
- A more productive use of time and resources: by removing power point presentations, lecturing and dictation up to a 90%, time is now employed in making questions, comparisons and analyzing new materials that supports the explanations.
- Higher interest in the topics: since the class is designed with several learning strategies, there is a dynamic that prevents lack of focus, boredom and monotony.
- Usage of metaphors, infographics and concept maps allows higher retention: similarities and analogies help learning, and as students themselves say: "we can retain more easily with examples".

This change has allowed breaking paradigms and understanding that there are other ways for engineering education that can replace the traditional ones, and can support higher learning in the classroom. In addition, it adjusts with the new pedagogic models that some universities want to employ, seeking that their students use knowledge more creatively to solve problems in practice.

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