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AN ENGINEERING APPROACH FOR CONTINUOUS IMPROVEMENT IN ENGINEERING EDUCATION

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I'm working into "EAFIT University" in Colombia with the topics related The Definition of Design The Purpose of Design The Philosophy of Design The Process of Design To help promote design principles, methods, and technologies that lead to the education in engineering for the creation of products and services. I was the director of Mechanical Engineering Program and Co-director of Engineering Product Design program, and also, I had the academic coordination the Design Area. I'm working for several years (15) in the diffusion academic the Design topics.

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Introduction.

Nowadays there is a common concern about the quality of the training of future engineers to become not only technically exceptional but also innovative and prepared to work in an ever changing global economy and to meet the different challenges they'll face. For instance, many of the visions of the '2020 Engineer' [1] suggest that the education of the XXI Century engineer must be: (i) student-centered, (ii) supported by applied research, and (iii) provided with meaningful experiences at all times. Thus, an engineer must have the necessary skills to address scenarios such as the next scientific revolution, the revolution biotechnology in a social context, prevention and recovery from natural disasters, and globalization.

The Educational Guiding Principles of EAFIT University's Institutional Educational Project [2] has recognized that human-centered education requires a curricular perspective that offers more flexible programs that allow students, according to their preferences and skills, to choose between vocational training, human sciences, or culture and art. In tandem, from the pedagogical point of view, it makes learning --as opposed to teaching-- the core of its educational processes switching the focus of attention from instructors to students. These guiding principles are supported by three main objectives stated in EAFIT's Development Plan 2012 - 2018 [3]: (a) preservation of academic excellence, (b) research supported teaching, and (c) internationalization of the institution. These objectives were intended to not only for students to transfer knowledge to practical applications, but also to generate new knowledge through inquiry processes. Therefore, the attainment of these goals then requires a continuous evaluation approach that will result in continuous improvement of plan of studies and curricula.

In this paper we describe the established educational and continuous improvement strategies the School of Engineering has adopted that are aligned with EAFIT University's institutional educational initiatives. Specifically, we will describe an engineering approach to curricular design grounded in: educational research, engineering education, and interactive educational communities of practice. Finally, we also present how this methodology was implemented in the School of Engineering of EAFIT with support from Purdue University.

Institutional Context and Motivation.

The School of Engineering at EAFIT University has defined the core of its pedagogical model and curricular structure, which characterizes EAFIT's students and graduates, around five pillars: project-based learning, modeling and simulation, integration of technology and design through construction of artifacts, the characterization of matter and detailed management and development of new projects. From this definition, and lead by the Dean of the School of Engineering, curriculum proposals were constructed for each undergraduate program between the years 2006 and 2007. These proposals were developed in different phases moving from rethinking unique disciplinary curricula of each academic program to identifying the common themes across them.

In addition, there was a close relationship between the newly pedagogical model and curricular structure and the design of the engineering building inaugurated in 2010, which was born as part of the celebration of the 30th anniversary of the establishment of the School of Engineering. The building was conceived with design of spaces that promote students to capture their ideas in a tangible way and to become masters of their own learning: "The engineering building was designed thinking in spaces where learning predominates throughout life "[4].

The building has five floors each one with a specific purpose. In this design, outcome of one floor becomes the input for the lower level floor. The fifth floor called "space for the creation and generation of solutions" is a site where instructors, students and businessman, work together to solve problems, generate discussions and schedule exercises that promote creation. It is a place where collaborative work is performed for generating the initial ideas for the projects.

The fourth floor, called "space for the modeling and simulation", is defined as a learning - centered place where students can explore and use software, solve homework as needed and work individually at their own pace. This place is where modeling and simulation of the possible solutions for the work proposed on the fifth floor is done.

The third floor, called "space for the characterization of matter", is defined as a space for service where students perform activities on the interface between suppliers and customers. This is where deep analysis of cases and problems is performed.

The second floor, called "space for technology integration", is where integration between theory and practice is promoted. In this space students learn to: methodically approach the design technical systems, integrate mechanical, electrical, electronic, and computing knowledge into devices, instruments and machines, and configure the various subsystems of a system by selecting and integrating mechanical, electrical, electronic, and computer technologies.

Finally, the first floor, called "space for production", is a place that includes a manufacturing and design machine shop and where engineering materials are worked. This is where the students have an opportunity to practice with and experience the different solutions proposed to projects previously identified on the upper floors.

In summary, the result of the work done in each of the spaces of the building are the input for the next floor: the fifth floor is a space built for collaborative projects and where the first ideas are generated, the fourth floor is the place to work on modeling and simulation of those ideas, the third floor is a place of transit for the immaterial and material, the second floor is where technology is integrated to the project that is being developed, and the first floor is the place to build the product conceived in its entirety. Such spaces and strategies have encouraged rethinking the curriculum of the School of Engineering in a way that, when integrated with processes for scientific research in education, may allow significant changes in learning environments and promote the renovation of the pedagogical strategies.

Thus, we propose an approach for designing curriculum for the School of Engineering of EAFIT University based on three types of processes: (a) scientific research in education, which allows the definition and construction of research and innovation projects that are based on the needs and difficulties found in specific areas or subjects by establishing a research question and

carrying out processes of conceptualization, implementation and result analysis through action-participation methodologies; (b) engineering education in engineering, which transforms the learning process in the student by developing basic, professional, transversal and the engineer of the XXI century skills; and (c) the creation of an interactive educational community made up of instructors, heads of programs and departments of all academic departments of the School, where knowledge management and collaborative work around socialization experiences through real and virtual spaces take place.

Implementation Process.

The implementation process of the above mentioned strategies, curriculum and pedagogical model for the School of Engineering of EAFIT University was based on three main approaches: (a) educational research, allowing the definition and construction of research and innovation projects that are based on the needs and difficulties found in specific areas or subjects by establishing a research question and carrying out processes of conceptualization, implementation and result analysis through action- participation methodologies; (b) engineering education and engineering instructional design, transforming student learning processes by developing basic, professional, transversal and the engineer of the XXI century skills; and (c) the creation of an interactive educational community for faculty members, heads of academic programs and departments, and the Dean of the School of Engineering. We now describe each of these three main approaches.

Faculty Development through Communities of Practice.

The community was integrated with the goal to provide professors with conditions for them to generate knowledge and ideas and physical spaces to exchange and share information permanently. It is important to understand that all knowledge is intrinsic to the people, it is generated as part of the interaction process between them and that information has little value by itself and only becomes knowledge when it is processed and socialized.

Networking is critical to create new knowledge. Community members have the opportunity to exchange, potentiate, generate and share information. It is said that a network becomes an interactive educational community when knowledge networks begin to define specific goals and visions are shared by its members in face to face and virtual spaces (learning environment). When (a) discussion topics are about their experiences and have a consistent and concerted way, (b) work is managed and promoted to enable innovation, and (c) project development is focused on a specific topic responding to didactic and pedagogical needs, it is said that the network becomes an interactive educational community. [5]. Thus, a learning community was created with of instructors, program heads, department heads and the Dean.

For this community the goal was sharing experiences and generating not only a reflexive and critical review and assessment of practices and results in their work, but also initiatives to promote openness to innovation, design and development of projects focused on improving student learning and teaching, and enable a scholarly approach to generate knowledge and promote research and investigation activities in education. The goal of this community was to then produce and share a pedagogical culture about values, principles, concepts and practices in curriculum, instruction, assessment, organization and functioning of the institution.

Interaction spaces, both physical and virtual, were created to support research projects where each participant could share their knowledge, experiences in classroom practices, and design and construction of innovative approaches in engineering education. One of the virtual spaces adopted for our proposal is the CLEERhub [6], which is a platform designed to support collaboration in research and education processes, and is aimed at all the issues surrounding engineering education. In this space, members were provided with tools to post content, materials, tools and generate ideas about engineering educational research.

In addition, face-to-face spaces were also provided for socializing experiences and permanently support research and innovation processes. One of the proposed spaces is Thematic Cafes (Cafés Temáticos), which is a methodology for knowledge management through knowledge dissemination, collaborative work and socialization experiences. In this way, both spaces not only enabled permanent collaborative work, but also promoted constant reflection, update and monitoring of the different educational research, and management of permanent renewal of the curriculum.

Our proposal was also coupled with curricular, educational, methodological and assessment strategies, allowing not only to transform classroom practices and academic programs, but also the processes of curriculum management, teaching, research and management of an institution. These strategies, described below, were created with the goal of strengthening the faculty development, the learning management and continually expanding the research capacity of the community of the School of Engineering.

Educational Research, Engineering Education and Instructional Design.

The School of Engineering established a roadmap for the development of this proposal. Initially, teams composed of instructors from each of the seven academic departments were created: Civil Engineering, Product Design Engineering, Mechanical Engineering, Process Engineering, Production Engineering and Systems Engineering (computer science). Members of the team consisted of two or three instructors from each department and their department heads. These working groups collectively were responsible for designing educational research projects based on a research question that were guided by the needs and difficulties of specific areas and disciplines. Additionally, different opportunities for reflection and socialization, led by the Dean of the School, were created such as: workshops, thematic cafes, meetings, and CLEERhub use, among others.

Two workshops were offered by a faculty member from the College of Technology at Purdue University who also holds a doctoral degree from the Engineering Education Program at Purdue University. These workshops were originally created by Drs. Ruth Streveler and Karl Smith as part of a faculty development program created to promote rigorous research in engineering education [16]. One of the workshops was focused on an introduction to educational research in engineering education, aiming at applying educational research processes in their teaching based on the different needs and learning difficulties experienced in their classrooms. The second workshop focused on an introduction to instructional design and continuous improvement approach to curricular design and educational innovation.

The forty instructors who attended the workshop had the opportunity to think about the nature of their pedagogical style as described by [16] for teaching engineering exploring questions such as: (a) Do I teach and assess the same way I was taught? (b) Do I teach and assess using theories and accepted teaching practices? (c) Do I teach and assess students' performance and make improvements based on the feedback received? (d) Do I get involved in educational experimentation in my courses and share results (e.g. conferences, seminars)? and (e) Do I conduct educational research and publish articles (in educational research) in indexed journals?. The results of an interactive survey showed that 60% of the participants were identified with option (c), while 20% were identified with option (e), 10% were more familiar with option (d) and finally, the other 10% with option (b). Interestingly, once discussed these results among participants, professors realized they were not able to discern between these statements as focused on their scholarly approach to engineering education and their research approach to their technical areas of research.

The two workshops addressed three main issues: current trends in disciplinary teaching and curricular design, educational research models, and formulating educational research projects. This collaborative workspace became an important starting point for the analysis, design and construction of different learning experiences focused on engineering education by applying scientific research in education, which may generate a significant change in the teaching and learning in each of the disciplines. Each of these experiences has become innovation projects in engineering education based on the needs and learning difficulties among students or areas of the curriculum and research processes that need improvements. These innovation projects, through support, counseling and socialization meetings have resulted in the creation of new teaching strategies and significant changes in different school courses.

On the other hand, the Thematic Cafes, a methodology for knowledge management through the development of socialization strategies, start from specific topics in the innovation process where the sequence of topics to be discussed in each of these spaces are defined in such a way that all participants can benefit from them and such topics promote the generation of new proposals. For instance, the first Thematic Cafe: EAFIT's Engineer Skills moderated by the Dean of the School, led to a deep reflection from instructors, Heads of Department and Heads of programs around the graduate profile that should be achieved by all EAFIT students and graduates in any of the engineering disciplines offered. Other topics discussed at the consecutive cafes were:

1. Curricular strategy and project-based pedagogy.
2. Field trips as a learning experience and a teaching tool.
3. Competency-based curriculum design.
4. Assessment processes supported by information technologies and telecommunications.

In parallel, we conducted a knowledge management workshop that was intended to guide instructors in building different knowledge models associated with each project in a way that they could visually represent, in a more accurate and detailed manner, the problem and the central research question of their innovation projects through concept maps.

One on one periodic meetings have been held with each team of instructors and a group of educational researchers from Proyecto 50 to discuss and coach them in the implementation of their educational innovation projects. These consultations have allowed not only for the

professors to receive support from a thematic expert but also have promoted different analysis, agreement, reflections, dialogues and discussions among participants.

Preliminary Outcomes.

The development of innovation projects has resulted in a systematic process in which the participating instructor starts from a central research question that requires processes of conceptualization, implementation, and results from result-analysis experiences. These projects intended to introduce new interactions in the classroom and transform educational practices where innovation and production of digital educational resources are merged to offer the students enriched learning environments.

These educational innovation projects have encouraged instructors to network in structured, collaborative and research-full interactions where they have the opportunity to review new information, reflect on their own practice, and analyze the results being obtained in the classroom. Additionally, it motivates them to develop the basic skills in the fields of teaching strategies, planning, assessment and evaluation, to seek new avenues of educational experimentation that may give better results in their work and to encourage the creation of new contents or adapting existing contents to the current needs in their area of expertise.

Some of the innovation projects formulated by instructors of the School of Engineering are: (1) identifying learning difficulties in the course of statics, (2) transformation of the automatic control course by the development of skills, (3) development of capstone projects in production engineering and systems engineering (computer science), and (4) the identification of how the course of graphic expression can develop better skills for engineers in their creative process, among others.

The proposed research projects have produced results such as: (a) reducing the dropout rate from 30% to 10% in the Statics course, which is part of the basic training of engineers in the areas of Mechanical Engineering, Civil Engineering, Production Engineering and Product Design. This was achieved with the construction of an automatic assessment and feedback system that allows students to perform activities such as: review of content, practical exercises and presentation of online exercises and workshops; (b) micro curricular redesign of integration projects (capstone courses) in production engineering in the manufacturing area where the core competencies to be developed in the student were defined based on the actual stages of a production plan; and (c) the competence-based redesign of the Automatic Control course, with analysis of the initial and final profiles of students taking the course and building knowledge models for describing in detail each of the skills developed there. Similarly, there are innovative projects that reflect that institutional support is essential, where instructors can have time and space to conduct scientific research processes in education.

Conclusions and Future Work.

Interactive educational communities formed under this proposal where participants socialized experiences, generated not only reflective and critical revision and assessment of the practices and results in their work, but also created initiatives to promote openness to innovation, design

and development of projects focused on improving student learning and teaching in the academic community. These initiatives enabled joint research processes in order to generate knowledge and promote research and investigation activities in education. This effort generated a shared educational culture about values, principles, concepts and practices in curriculum, instruction, assessment, organization and functioning of the institution.

The School of Engineering at EAFIT University, through this new approach, has raised awareness that we must have curricula based on educational research and interdisciplinary management, that a transformation of the training process is needed, and that it is also important to achieve a strong graduate profile in their students and graduates according to global requirements that must be faced by the XXI Century engineer.

Bibliography.

[1] Engineering, NA of. (2004). The engineer of 2020: visions of engineering in the new century. The National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=10999 .

[2] University EAFIT. (2008). Institutional Educational Project. Medellin, Colombia. Retrieved from http://www.eafit.edu.co/institucional/Documents/pei_eafit.pdf

[3] University EAFIT. (2011). Development Plan 2012-2018. Medellin, Colombia. Retrieved from http://www.eafit.edu.co/institucional/calidad-eafit/investigacion/Documents/Plan strategically% C3% 2012-2018.pdf A9gico.

[4] Rodriguez Garcia, Alberto. (2012). Eafitense Engineer Skills - Presentation themed cafe EAFIT Project 50. Published in: https://cleerhub.org/groups/proyecto50/caf% C3% C3% 81tico 89_tem% .

[5] Zea Restrepo, CM, & Atuesta, M. R. (2007). Towards an interactive educational community (First ed.). EAFIT Publishing Fund.

[6] Website: http://cleerhub.org/

[7] Wenger, E. (2006). Communities of practice. Retrieved September 18, 2012, from http://www.ewenger.com/theory/ .

[8] Wenger, E. (2010). List of resources | Wenger-Trayner. Retrieved March 5, 2013, from http://wenger-trayner.com/map-of-resources/

[9] Wenger, E. (1999). Communities of Practice: Learning, Meaning, and Identity. (UC Press, Ed) (p. 336).

[10] Wiles, Jon. (2005). Curriculum essentials (2nd ed.). USA: Allyn & Bacon.

[11] Shavelson, R. (2002). Scientific research in education. (RJ Towne Shavelson & L., Eds.). The National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=10236
[12] Grau, A. (2007). Knowledge management tools. Retrieved from http://docencia.udea.edu.co/ingenieria/semgestionconocimiento/documentos/Mod7_HerrTec.pdf

[13] Pérez Rodríguez, Y., & Castaneda Perez, M. (2009). Knowledge Networks. Retrieved September 9, 2012, from http://redalyc.uaemex.mx/redalyc/pdf/1814/181421573001.pdf

[14] Wiggins, G., & McTighe, J. (2005). Understanding By Design (2nd Expand., P. 370). Assn. for Supervision & Curriculum Development.

[15] Wenger, E., White, N., & Smith, JD (2009). Digital Habitats, stewarding technology for communities (First Edition., P. 250). CPsquare.

[16] Streveler, R. and Smith K. (2006). Conducting Rigorous Research in Engineering Education. Journal of Engineering Education.

[17] Crawley, E., Malmqvist, J., Ostlund, S., & Brodeur, D. (2007). Rethinking Engineering Education: The CDIO Approach (p. 300). Springer.