THE AXIOLOGICAL AND EPISTEMOLOGICAL FOUNDATIONS OF A PDE PROGRAM

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ABSTRACT
The structure of a Product Design Engineering (PDE) Curriculum has two dimensions., One, the axiological, allows a meaningful division of the areas to be considered by discussing areas such as *knowing to know, knowing to be* and *knowing to do.* The other one, the epistemological, defines the content of the axiological areas. This paper describes how this two dimensions can be used to structure a PDE curriculum using the program at Eafit University as a case.

Keywords: Design Education, Curricular Development, Project Based Learning

1 INTRODUCTION

Design is perhaps one of the most ubiquitous activities of modern societies. Practically everything that surround us is the product of a design process. Designers, in the formal sense of the word, started being formed in the apprenticeships of certain arts and crafts. This tradition slowly gave birth to informal education programs in vocational schools during the middle ages until the early 20th century after which, it entered the University.
The constant quest for more efficient systems, better production means, culturally aware products etc. forced design to respond moving from the conceptualization of a form to embody a function to considering other areas such as environmental issues, interactivity, friendliness, emotional aspects, and a very long etcetera. It also moved from everyday, utilitarian products, to more complex systems, including building, manufacturing plants, planes, automobiles, etc.
The significant role design plays in our lives means that design, as a profession, is not only concerned about conveying the technological and scientific knowledge necessary to create products or artifacts, but should as well address cultural, political and philosophical issues to found its social responsibility. Designers must have a better understanding of the people that will use their designs, and the context in which they will be used. The design process needs to articulate then the aesthetical and the technical. On the one hand, the product must contain a stylistic character, follow design trends and comply with certain cultural demands and, on the other, it must fulfill industrial requirements, production constraints, quality, cost effectiveness and functional performance.
It was this expansion of the scope of design what stimulated the use of knowledge generated in other disciplines that were developed separately, like chemistry, electronics or physics, and more recently, biology, social studies, psychology etc. It shifted design from a *practice* to a *discipline.* This shift means that a different type of designers are needed. As the complexity of the products increased, the guild-oriented training was no

longer sufficient. The new education required posed issues that needed to be addressed in two ways. Firstly, by means of a systematic description of the design processes (methods) and reflection on the design activities and secondly, with the creation of a cross-disciplinary language that would allow the inclusion of knowledge from other disciplines.

The methodological issue was addressed by the methodology movement that appeared in the 60's, motivated partially by the demands of the military and partially because of the advent of cognitive psychology. Some researchers, like Alexander [1] and Archer [2] observed that design is an activity that does not only require creativity, but also the application of formal knowledge, following a logical, systematic way of thinking. The methodology movement posed as an objective, to create systematic methods and tools to better conduct the logical analysis in order to unload the designer to engage in the creative aspects of the problem solving [3].

The second issue, the creation of a cross-disciplinary language, was addressed by the creation of education programs in Product Design Engineering (PDE). Even though PDE has existed for some time, it still has to be acknowledged and developed as a *discipline* and as a *profession*. Product Design Engineers (PDEng) are often recognized neither as designers nor as engineers. The reasons behind this obey to the fact that 'design' is seen primarily, because of its origins in the guilds, as a form of applied art or craft skill which is difficult to convey to the engineering world. A few schools, however, have taken the challenge of developing curricula that, without subtracting the very essence of design as a creative process, incorporate an engineering component.

The development of such curricula is not a trivial task. It needs to answer questions like what elements should be present in the program and why. How can engineering inform a PDEng? What kind of projects should be included and how the selection of the projects determine the rest of the subjects to be taught? This paper discusses these questions using as an example a PDE curriculum developed at Eafit University in Colombia.

2 THE FUNCTION AND STRUCTURE OF A PDE CURRICULUM

In any education program, the curriculum needs to be conceptualized from at least, four perspectives: The teachers', the students', the program's, and the institution's [5], [6]:

- For the teacher, the curriculum means to plan the content of the courses (subject matter), its scope and detail; to select the pedagogical means to deliver that content (learning theory and strategy), and the didactics (learning tactics and methods); and to make clear the learning objectives. It also means answering questions about suitable ways of instruction (how to teach?) and recommend teaching media and material.
- For the students, the curriculum means assimilating the content, developing the skills, learning to learn and developing as a professional and as a social individual.
- At a program level, the curriculum involves the coordination of the content and the objectives of the different courses, i.e., planning how content and skills mastered in one course can be transferred to another.
- For the institution, the curriculum is the means to fulfill its responsibility to society, facilitating the preservation of existing knowledge, the creation of new one, the formation of specialists and the education of citizens.

The conformation of a curriculum that fulfils these requirements has two dimensions. One, the axiological, allows a meaningful division of the areas to be considered. It provides the pedagogical means and gives shape to the vision of the program at an institutional level. The other one, the epistemological, provides the content and structure at a program level. It will orient the topics to be instructed and will determine the interaction between the knowledge acquired and the skills developed in different courses.

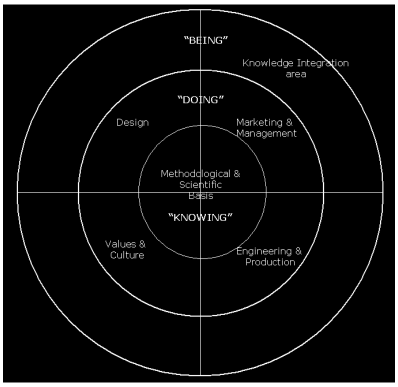

Figure 1 Axiological dimensions and areas considered in the curriculum

Axiologically, the curriculum is structured in three areas: knowing to know, knowing to be and knowing to do [10].

1. The area of the scientific and methodological foundation, *knowing to know*, contributes the scientific content and the research methods that allow the professional, not only to make use of the existing knowledge, but also to manipulate, adapt and test it, and to discover and generate new one.
2. The area of professional development, *knowing to do*, contributes the knowledge, the abilities and skills necessary for the professional practice.
3. The social and humanistic area, *knowing to be*, contributes to the formation of the individual, considering that he/she is a being of knowledge with consciousness, a social being and a carrier and generator of culture. (Figure 1)

Epistemologically, the curriculum will be informed by three perspectives that are closely correlated to the axiological areas presented above: First, the knowledge that informs any engineering program and a PDE program in particular. Second, the structuring elements to be considered in a PDE curriculum. These structuring elements are deducted from a taxonomy of design research, a theory of artifacts and the departments in which industries are typically organized. Finally, the structure of an area in which the method, the theory of the artifact and the fundamental knowledge can be integrated.

3 THE PDE CURRICULUM AT EAFIT UNIVERSITY

3.1 The Knowledge that informs PDE: *Knowing*

The courses that conform the core of every engineering curriculum can be classified in two ways: those courses with a discipline specific character and those courses with a professional character. The first ones have the purpose of founding the studies in knowledge and methods derived from science: exact sciences (mathematics), natural sciences (mechanics, physics, etc.) and sciences of the artificial. They are usually common to most engineering programs.

The second ones have a pragmatic goal: to educate with knowledge and procedures derived from technology. These courses give the professional character to the program: drawing, solid mechanics (statics, dynamics, mechanics of materials); fluids mechanics and thermodynamics; technical systems (mechatronics, systems theory, conceptual design); mechanical systems (structures, mechanisms, thermodynamics); electronic systems (circuits, automatic control). These professional courses are the ones that teach the student how to *do* the things that are particular to Product Design Engineering. The structure of this area is discussed in the next section.

3.2 The professional area: *Doing* what a PDEng does

Learning to do the things a design engineers does is the object of this area. It determines the subjects that give character to the profession. This area is informed by a taxonomy of design research that considers three areas: people, products and processes. Firstly, it considers the designers way of knowing, their cognitive processes and their design strategies, i.e., *design epistemology*. Secondly, it considers the study of practices, processes and methods in design: *design praxiology*. Thirdly, *design phenomenology,* the study of the objects or artifacts to be designed, their form and configuration [4].

Additionally, the curriculum must reflect the fact that the products it considers are industrial, mass produced and the result of the integration of multiple processes that can be associated to the functional division of industries and the names of the departments in which they are usually organized (design, marketing and production). It must, as well, reflect the aspects that emerge in some of the design process models (like the VDI 2221, e.g.) and in the curricular structures of some design programs. The industrial, methodical and curricular distribution shows common aspects that must be considered during the product development process, namely, planning, design, production, sales, use and disposal [12].

This is to indicate that the courses in a PDE program have a double purpose. The first one, to help concretizing the artifacts that are crucial to the discipline: design of *technical* artifacts, production of *physical* artifacts and marketing of *social* artifacts [7]. This gives origin to courses such as conceptual design (artifacts theory), form theory and systematic design.

The second purpose appears when the topics that are considered fundamental are contextualized, within the frame of the industrial units of design, marketing and production. In this way, topics such as design for assembly, design for manufacturing and design for costs and new product development appear in the curriculum.

In this way, there will be some courses that focus on the notions that are considered crucial to the design process, being oriented, from this double perspective, to the study of methods, project management and artifacts theory. There will be others as well, that will focus on the contextual aspects. That is, on the practices of marketing, production management or any other that might appear in the life cycle of a product: maintenance, use, recycling, etc. There are therefore courses that study the methods in a general way, such as systematic design, but there are others that study methods in a contextualized way: design for X, design for manufacturing, design for assembly, strategic design, etc.

Following these considerations, the courses in this area are then grouped in three areas: design, marketing and management and engineering and production. There is, however, a fourth area that considers the human factors of the final users, their situation, and the cultural aspects necessary for a good integration of the designed products in the social environments in which they will be used. This is the area of values and culture.

A PDE curriculum, besides these foundational and professional subjects, must include the projects area, which emphasizes the *praxis*. This area is used to integrate knowledge in methods, through actions that lead to the concretization of objects or artifacts.

Table 1 Objectives, context and artifact type for each Design Project (DP). Type of artifact follows Hubka and Eder's classification of technical systems.

Course	Pedagogic Objective	Context	Type of Artifacts	Examples
DP1	Communication	The Identity	Manual	Fast food sell points
DP2	Metacognition	Household	Manual	Trash bins
DP3	Conceptualization	Information	Manual	Machines to explain other machines
DP4	Production	Workspaces	Mechanical	Nail guns, fret saws
DP5	Method. Strategy	Mobility	Mechanical	Dune Buggies
DP6	Contextualization	Electric./gas appliances	Mechanical/Auto	Bottles sterilizer, ovens
DP7	Product & Company	Entrepreneurship	Man./Mec./Aut.	Scooter, furniture
DP8	Design Management	Entrepreneurship	Man./Mec./Aut.	Transportation

In summary, there are three kinds of courses to be included in a PDE curriculum. Ones whose focus is to provide fundamental , scientific knowledge; another ones with a clear orientation towards the profession, that serve as an epistemic base for the scientific and technological knowledge. Lastly, those that form in the students the skills to carry out the design of an artifact: planning, conception and execution. The latter ones are discussed in the next section.

3.3 *Being* a product design engineer: the knowledge integration area

This is the third perspective from which the curriculum has been conceived. In this perspective we want to emphasize the practical aspect, and the will to teach the students a discipline based on, for instance, a theory of functional artifacts and on methods and procedures that have been proved. A PDE program starts from the premise that a discipline like it should be taught based on projects, partially because of the amount of artistry involved and partially because projects provide the frame over which all the skills of a PDEng develop [8],[11].

The knowledge integration area is composed by eighth design projects (one per semester), an internship (compulsory for all the programs within EAFIT University) and the graduation project. The knowledge integration area seeks that the student becomes a Product Design Engineer by *being* one from the praxis of the design activity. This means that the design education is based on a 'learning by doing' philosophy .

In general terms, the Design Projects have a common structure based on three fundamental elements:

- The *pedagogical objective* of the design project, which constitutes the core of the course and the purpose behind the design exercises performed by the student.
- The *context* of the design project which allows the student to know problematic issues related to the diverse segments of design.
- The *design and construction of artifacts*, whose intention is that the student acquires and applies technical and formal knowledge to the resolution of problems related to the design context that has been defined for the exercise.

Table 2 Structure of the Design Projects

		DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8
Design Epistemology	Cycle	Basic			Transition		Professional		
	Skills	logos			art + techn_		techn_ + logos		
	Strategy	Divergent				Convergent			
Design Praxiology	Methods	Analysis			Synthesis		Evaluation		
	Actions	Explore			Generate		Communicate		
Design Phenomenology	Context	Design			Production		Marketing		
	Type	Technical			Physical		Social		
	Artifact	Manual			Mechanic/Automatic		Auto/Manual/Mech.		
	Detail	Functional Models				Prototypes			

The conjunction of these three elements defines the subjects, the scope and the methodological strategies for each Design Project. Considering the vision of the PDE program, its conceptual justification and the professional profile of the PDEng, the PDE Department has defined the objectives, contexts and artifact type for each design project. This is summarized in Table 2.

This selection of objectives, contexts and projects follow a more elaborated structure that conforms to the structure used to construct the rest of the curriculum. This structure is summarized in Table 2. There are three main areas that correspond to the aforementioned taxonomy of design. The considerations are based therefore on the designer, the design processes and the types of artifacts to be designed, as well as the level of detail of the design outcome.

In all projects, the students must follow the entire design process, and in all projects an artifact is asked. What changes in where the emphasis is put. For instance, in design projects 1 to 3, the emphasis is on the analysis part of the process, describing the contexts in which the product is to be used, formulating the problem, generating lists of requirements, etc. Design projects 4 and 5 concentrate on synthesizing solutions to given problems, the focus is on finding suitable solutions and embodying those solutions on manufacturable products. Up to design 4, the results are functional models, after that, the outcome will be fully testable prototypes.

Form the Epistemological point of view, the Design Project structure must show how the scientific and methodological foundations that conform the *knowing* of an engineer are applied in an orderly fashion. As it was shown previously, the 'knowledge flow' for an engineering program starts with the basic sciences (logos), then the applied sciences (art + techn_) and it finishes with the construction of certain objects (techn_ + logos). This is taken into account in the Design Project structure in three ways: the cycle (basic, transition, professional) where the Design project is, the kind of product to be designed, and the outcome –in terms of the object made by the students– of the course (functional models or prototypes).

Finally, from the point of view of the thinking processes of the student (operations, co-ordinations and actions) the Design Project sequence is configured in such a way that in the basic level the emphasis is put in the operations (individual work over group work), in the transition level the coordination's are favored (group work over individual work) and in the professional level the emphasis is laid on actions and on results.

In order to see the explained structure in action, lets take for example Design Project 5. The students in this project must follow the whole design process but the emphasis lays on the synthesis phase, were convergent thinking plays a decisive role. This enables them to think about the physical artifact –the one that enters a production system– and the product designed by the students is 'mechanical'. The assignment of the design project is such that the students must work in large groups (6 to 8 students per group) favoring coordination processes. At the end of the course the students must deliver a prototype of the product designed during the course. The organization of the courses in the curriculum by semester depends very much on the type of knowledge and skills that are required for each of the design projects. That is to say, the objectives and expected results of each of the design projects condition the organization of the rest of the curriculum.

4 CONCLUDING REMARKS

The experience with the program has been very positive. Since its inception in 1999 it has admitted more than 600 students, the first of which will graduate in December this year. The short life of the program has not produced results to allow important or radical changes in the structure of the curriculum. However, the content of some subjects and the organization of some design projects have been improved.

In contrast to Europe, in Colombia there is little design tradition. For this reason, instead of working towards the development of design methods, the effort is put into adapting existing ones to context and idiosyncrasy of our industries.

The design projects are organized by topics (mobility, functionality, autochthony) and do not change in time. For instance, design project 5 considers mobility and students design vehicles for various contexts (handicapped people, mail delivery, etc.). This approach allows (i), the generation of significant expertise in the teaching staff, which is better prepared to advise the students; (ii) the achievement of very elaborated results, as new products build up on previous experiences; and (iii), the generation of infrastructure for those projects such as laboratories, technical staff, information centers, testing procedures etc. The quality of the achieved results already attracts the attention from industry, which is willing to participate sponsoring more complex and expensive products.

The intention in the future is to improve the infrastructure, with manufacturing facilities specialized in the topics treated in the design projects, with qualified personnel to assist the students in the construction of the prototypes, so these are of outstanding quality. These workshops will have technicians in mechanics, electronics, informatics and production.

During these years there have been, of course, difficulties. Although great effort has been put into trying to prevent this, the fundamental knowledge that is relevant to a design situation is some times taught separately from the design activity itself. This is caused by the fact that students from many different programs attend the same physics, mathematics, mechanics of materials, etc. courses. These courses cannot be customized to particular (PDE)students. The consequence is that students have difficulties encoding this theoretical knowledge in terms of issues they face when they are designing.

Nonetheless, the results of the design projects, which are the best way we have to test the quality of the program, are most encouraging. Some of them have become already commercial products, several students have opened their own companies and industry is eager to take interns. The best test, however, will be given in time, when those graduates start changing the face of the industries in the Country.

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