DEVELOPMENT OF LECTURES ON COMPUTER TOOLS FOR POSTGRADUATE STUDIES IN DESIGN ENGINEERING ORIENTED TO COLOMBIAN INDUSTRY NEEDS

David Rios-Zapata, Gilberto Osorio-Gomez,
and Ricardo Mejia-Gutierrez
EAFIT University
Colombia

Abstract

The impact of computer tools in how products are being designed has become an important point in implementing new technologies at the industrial level. Moreover, in a developing country the implementation of new technologies is a must in order to be competitive worldwide. According to the needs and limitations of the local industry, new engineers are required to be prepared in the use of these computer tools, guaranteeing employability and versatility and adaptability to relevant computer tools. Here, a series of academic engineering lectures focused in teaching different computer tools throughout product life cycle and based on needs and limitations of local industry will be explained for a Colombian postgraduate programme.

Introduction

Computer tools usage has become an important issue in product design engineering, empowering designers in spending more time in creativity rather than in detail design (Robertson & Radcliffe, 2009) and increasing the success rate of launched products up to 60% (Valle & Vásquez-Bustelo, 2009). Additionally, the innovation promoted by the use of computer tools has a strong influence in how the problems are being resolved and that usage is restricted to the user's knowledge of the problem, and as it is mentioned by the German historian Joseph Weizenbaum, mankind only uses computers to resolve things that they have already solved once (Nowacki, 2010).

Based on those statements, it is important to familiarize the local industry with the use of world class computer tools during the whole product life cycle and their advantages. Nowadays, a certain number of engineers are prepared on some advanced computer tools, but their personal request to work with these technologies is not always supported by their companies, unless a direct profit is obtained or a quantifiable enhancement is presented, which is not always the case on developing countries. That is the reason why educational institutions should

prepare professionals in the use of computer tools and their benefits in product design and development processes.

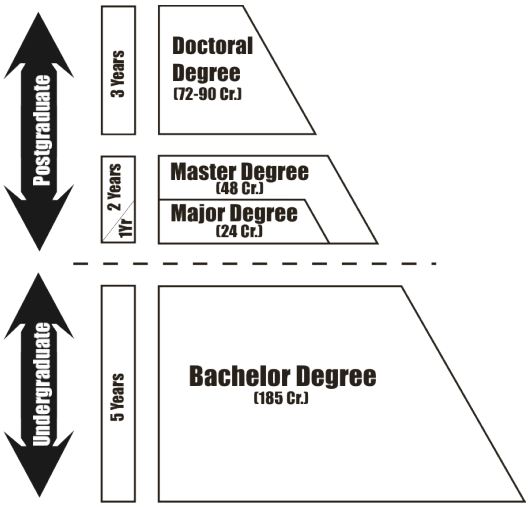
This paper proposes a series of postgraduate lectures (more specifically, an academic major[1]) to complement Product Design Engineering studies, oriented to computer tools usage in product design processes, based on the state of the art of some current academic majors related to design and computer usage, on the design methodology adopted in the EAFIT University[2] and on the results of a research on computer tools usage in Colombian product design industry.

State of the Art

Education System in Colombia

In Colombian universities, bachelor degrees take five years, and they make part of undergraduate programmes. Labelled as postgraduate programmes are Majors (a 1- year programme), Masters (2-year programme) and Doctoral courses (3-year programme). In Figure 1, a scheme about Colombian education structure can be observed. The credit system[3] is also depicted in order to show equivalences.

Figure 1: Education System in Colombia



[1] A major is postgraduate studies between the Bachelor and the Master.
[2] EAFIT is a private University in Colombia. EAFIT is the acronym of the Spanish: *Escuela de Administración, Finanzas e Instituto Tecnológico*.
[3] According to the Colombian Education Ministry an academic credit is equivalent to a student workload of 48 working hours per semester, which include working hours with professors and personal/individual work.

This article is centred on the development of the programme for an academic major. The methodology used in this stage of the research is the following:

- To review the academic majors offered inside the institution related to product design engineering
- To review programmes offered in Colombia related to product design engineering.
- To review some worldwide major programmes related to the usage of computer tools.

In EAFIT University, there are four Majors related to Product Design Engineering (PDE), classified into three categories: operative, managerial and educational. Operative ones are the Major in Mechanical Design and the Major in Product Redesign, which are focused in making a knowledge specialization in specific topics, using or not computational tools.

The Major in Product Design Management, in the managerial category, makes part of Product Design Engineering department, and is focused in management, creativity and market research. Even so, the usage of computer tools in product design is not the goal of the major.

Finally, in the educational category, the Major in Information Technology for Education is focused in the usage of informatics and computer aided education, but it is not focused on Product Design Engineering or on engineering or design activities.

Nationally, there is a Major taught at Antonio Nariño's University in Bogotá (the capital city of Colombia) focused into teaching different computer tools to support mechanical design (Universidad Antonio Nariño, 2010). This major is focused on presenting a specialization into some CAD, CAE, CAM computer tools, but does not offer computer tools for design tasks different from detail design stage (e.g., need, conceptual design, recycling, etc.).

There are several international courses centred on the usage of computer tools to resolve different tasks within product development processes. For instance, universities with a strong influence into Product Design Engineering bachelor taught in EAFIT University, such as Delft University of Technology and Politecnico di Milano, include in their postgraduate programmes courses centred on using different computer tools to aid product design processes (Politecnico Milano, 2010; TU Delft, 2010).

Moreover, other universities with PDE programmes are using different computer tools to support specific knowledge lines offered in their courses, such as Computer-Aided product design at Kingston University in London (Kingston

University, 2010) and User Interface Design at Norwegian University of Science and Technology (NTNU, 2010).

Some of those postgraduate programmes act as a motivation for developing a Major programme focused on teaching different computer tools that can be used through the entire product life cycle during a product development process (not only CAD tools), moreover, this major must be focused on fitting the real industrial needs and limitations in Colombia. On top of all this, it is important to recall that the major structure is supported by a systematic product design methodology.

Design Methodologies

Product design engineering is a programme centred on teaching different engineering concepts (such as calculus and physics) and blends them with different design methodologies, some from industrial design and many others associated to systematic design approaches. The most influent methodologies into product design methodology taught at EAFIT University will be shortly explained.

Pahl and Beitz systematic design method is by far the most known and used design methodology in industry and education (Tomiyama, 2009). This methodology can be summarized in four stages: planning and clarification of the task, conceptual design, embodiment design and detail design (Pahl et al. 2007). Another influent methodology is the one explained by Ulrich and Eppinger which is important since it has strong considerations in product specification, which is the foundation for the framework of the product (Yih Chong, 2009). The product design stages in this methodology are: product planning, concept development, system level design, detail design, testing and refinement and production ramp-up (Ulrich & Eppinger, 2008).

Besides, Baxter methodology is inspired in blending together the engineering and marketing roles in product development. The design process described in this methodology is: business opportunity, design specifications, concept design, embodiment design, detail design and design for manufacture (Baxter, 1995).

Lastly, it is important to recall the product design boundaries, where the concept of Product Life Cycle (PLC) is implemented. Within the frame of this research, the PLC will be focused into a concurrent engineering definition rather to a marketing definition. In this connection, PLC will be compound by six stages: need, design, production, distribution, usage and disposal/recycle (Kusiak, 1993).

All these definitions are valuable to understand how EAFIT University design methodology works, and how this methodology is related to computer tools usage. Finally the design methodology used at EAFIT can be described by the same four stages described by Pahl and Beitz (planning, conceptual design, embodiment design and detail design), but implementing other methodologies

tools (e.g., Ulrich and Eppinger, Baxter) in the stage of planning that assure a correct understanding of user needs.

Understanding how this methodology works, and which stages of PLC are being controlled, is a key factor in order to determine which types of computer tools can be used and taught during a design process.

Research on Usage of Computer Tools in Colombian Industry

In having an education configuration designed to suit real industrial needs, it is important to study industrial capabilities and real industrial situations in order to determine the specific needs of industry.

It is important to recall that Colombia is a developing country with a GNP of $283.1006 billion and a HDI of 0.689, where manufacturing industry is one of the more influent sectors within this HDI, representing 14.85% nationwide and 18.27% in Antioquia's region, region where EAFIT University is located (Ministerio de Comercio, 2010).

About industry economics, the classification that is used in Colombia is the CIIU (acronym for Clasificación Internacional Industrial Uniforme, or International Uniform Industrial Classification) (DANE, 1998). This classification takes his cue from the United Nations ISIC or The International Standard Industrial Classification.

Based on CIIU classification, the sectors where the computers tools usage research was made are leather manufacture, wood manufacture, plastic manufacture, mineral manufacture, metal manufacture, machinery, electrical equipment manufacture, manufacture of motor vehicles, furniture, and recycling.

According to the Chamber of Commerce of Medellín there are a total of 3004 enterprises, where 98% are small and medium enterprises (SME) (Camara de Comercio, 2010). Those 3004 enterprises are companies related to design and manufacture of different products, but up to this point, design methodology and computer tools usage inside those enterprises are unfamiliar.

Nevertheless, inside Product Design Department of EAFIT University there is data base of the more representative companies locally, which are the companies more suitable to a Product Design Engineer to work in it, and are companies where the product design methodology implemented are similar to the methodology taught at EAFIT University. Based on that 36-company data base (where names will remain confidential), a study about different computer tools was made.

Computer Tools Usage in Local Industry

This current study was made by doing face to face interviews with each company on the database. The interview structure was the following:

1. Presentation where the focus of the interview is explained to the interviewees.

2. Company presentation where some questions about the company and the company products are made. This part is important for understanding companies' needs and limitations.

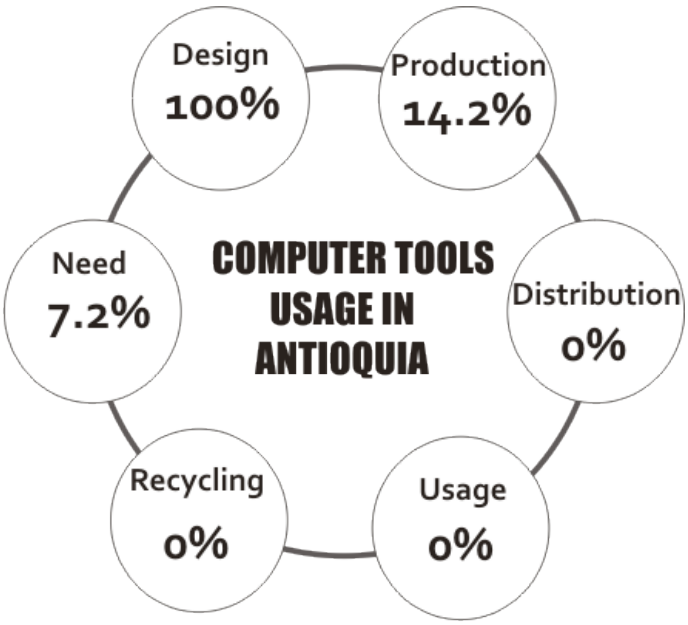
3. Product development process. In this part, it is asked companies to explain, step by step, the product development process they implement. Also, it is asked for each task they do, which computer tools are used.

4. Finally, it is asked how companies manage collaborative work and communication inside their design departments.

Results of Computers Tools Usage Study

The first result related to the study is centred in having a representation of how many computer tools are being used in the industry. As was mentioned before, within the frame of this research, the boundaries of PLC were already defined. In Figure 2, the percentages of usage of computer design tools in interviewed companies for each stage of PLC can be seen.

Figure 2: Results of Computer Tools Usage by PLC Stage

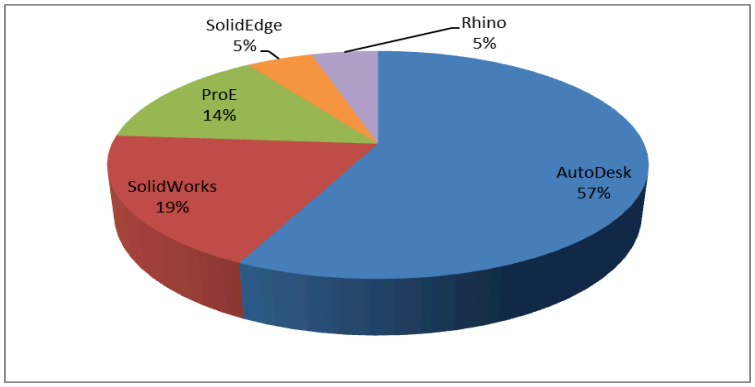


From Figure 2, it can be seen that it is an important lag in terms of implementation of computer aids into the different stages of PLC. Nevertheless, stages, such as production and need have a little participation of computer tools usage. Also, all interviewed companies use computer tools in their design stages.

In the stage of design, 100% of the companies use CAD (Computer Aided Design) tools to support their design process. In Figure 3, a discrimination between which specific software is used can be observed. Even so, none of those companies are using computer tools for conceptual or embodiment design engineering.

Also, in the design stage, 78.5% of the interviewed companies use CAE (Computer Aided Engineering) tools to validate their design development. From these companies, 55% of them use Autodesk solutions in their design processes. The 21.5% of the companies that do not use any CAE tool to validate their designs are all companies in the furniture industry.

Figure 3: CAD Tools used in Antioquia's Industry



About the other PLC stages, need tools are those helpful to identify user requirements. That 7.2% makes part of companies that are located into the furniture industry. Finally, the 14.2% of computer tools used in production stage are only CAM (Computer Aided Manufacture) tools used in moulding, which make part of injected plastic industry.

In collaborative work, it was found that 93% of interviewed companies are working in non-collaborative environments, and their work is limited to face-to-face interactions, letting relegated other types of collaborative work, such as remote and asynchronous work classification (Baecker, 1995).

About project and information administration, it was detected that 43% of companies uses Microsoft Excel as their project manager computer tool, while 50% uses basic project manager tools, such as Microsoft Project, and other computer tools based on Gant diagrams representations. Finally, only 7% of

companies are using advanced project and information management tools, such as ERP.

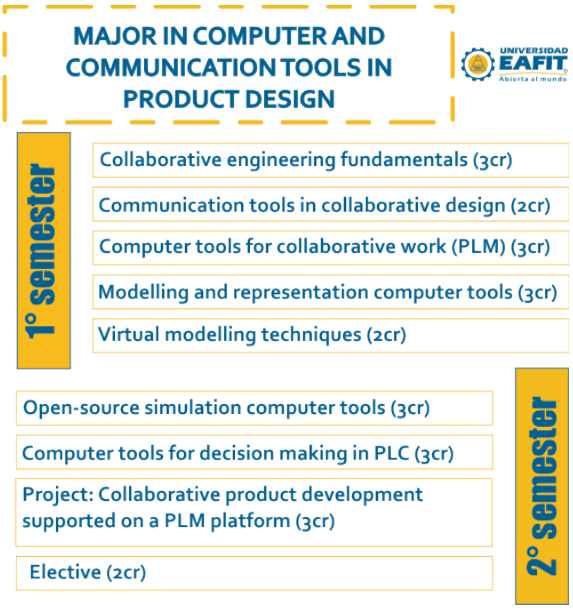
Analysis and Research Results

In the study about computer tools usage, it is clear that companies are using some computational aids on specific stages, especially CAD-CAM-CAE tools. Nevertheless, there is a lot of concern, because in the rest of stages inside PLC there is no usage of computer tools.

Additionally, when CAD-CAE solutions are analysed, there is one pattern that can be identified. The most implemented computer tools are the cheapest ones, even, if those tools do not offer the best performance according to their needs.

Finally, it was observed that companies do not use Open Source solutions in their companies, even if the implementation of those solutions does not require of an investment in commercial software. Based on the results of the study, the developed Major proposal can be seen on Figure 4.

Figure 4: Major in Computer and Communication Tools in Product Design



Conclusions and Further Research

This study leads to three main conclusions about the non-usage of computer tools in product design at industrial level:

- computer tools are not known (unawareness),
- engineers do not know how to use computer tools (unpreparedness), and
- high price (economic issues).

In terms of the developed Major, those insights and conclusions are represented into the following subjects: The first three subjects of the major are inspired in developing courses that show the importance of communication and information management in collaborative work environments: “Collaborative engineering fundamentals” is a subject centred on the theory of Concurrent Engineering and Product Life-Cycle Management (PLM). “Communication tools in collaborative design” will be centred on teaching different communication tools and communication and media richness importance in product design processes. “Computer tools for collaborative work” is a subject where PLM systems will be taught. In this subject commercial and Open Source solutions will be taught.

The four following subjects are focused to attack the unawareness and unpreparedness so those subjects are centred in practical use product design techniques through different PLC stages, stages that are not being yet experimented in local industry.

“Modelling and representation computer tools” and “Virtual modelling techniques” are subjects centred in different modelling methodologies, including Top-Down design (which is a methodology implemented in Concurrent Engineering and PLM), modelling for Virtual Reality environments and implementation of virtual and augmented reality environments y product design.

“Computer tools for decision making in PLC” is a subject where different tools will be taught. This Subject will be centred in different tools in need stage (due to the importance of need interpretation in product design) and disposal/recycling stage (due to environmental commitment).

“Open Source simulation computer tools” is a subject where Open Source tools for CAE and CAM will be taught. This might be one of the most important subjects in the Major, because it brings to industry solutions that can be implemented, due to low cost implementation.

The last subject, which is a “Project” called collaborative product development supported on al PLM platform, is focused in developing an entire design process implementing the different computer tools, techniques and methodologies taught at the Major.

It is important to recall the impact in Colombian industry due to Open Source software implementation. Usage of these solutions is an incentive to industry to use some computer tools in some stages of PLC (Opportunities due economic issues). For that reason, subjects such as PLM, simulation and decision making

tools are supported in an Open Source course assuring that the cost implementations of those tools in industry will be short, which means that it will have more chances to being implemented inside the industry.

Finally the next step of the research is focused in two parts. First part is developing a computer tools classification throughout product life cycle in product design and development process. The second part is developing an entire product design process supported by the computer tools and design methodology that make part of the major structure.

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