AN APPROACH TO TEACH MECHANICAL ENGINEERING IN ORDER TO AVOID CURRICULUM FRAGMENTATION AMONG TECHNICAL AND MANAGEMENT CLASSES

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Abstract: Today, engineering education, especially for technical subjects, is quite a challenge due to the high amount of new technologies available in the modern world along with the market competition. The current education system finds difficulties to follow the real speed of world's development and its requirements. Besides technological limits, a lack of integration between academic subjects is commonly observed. Many times, students struggle to link themselves to the knowledge obtained in correlated subjects, and understand how it all works together in real industry. Taken this issue into account, lecturers of Tupy Superior Institute - IST/SOCIESC, a modern engineering school in the south of Brazil, developed a successful education methodology for teaching engineering, by focusing on manufacturing plastic products. South of Brazil holds one of the most important clusters for metal mechanic and plastic industry in Latin America. The proposed educational method aims to improve students` view on process integration and minimizing the impact on the real industrial world after leaving university. It is achieved by simulating a Virtual Industry which produces plastic products. Each field in this manufacturing chain is considered one department of the Virtual Industry, and it is managed by a group of students. The method integrates the mechanical graduation course, propitiating a great improvement in the way of teaching engineering. The proposed approach of teaching engineering has been proved to be very capable and adequate in enhancing students` knowledge, in technical, scientific, management, human behaviour, working as a team. It also helps students` feeling about the real industrial world. The proposed method aids in avoiding educational fragmentation and giving support for engineering graduation in the contemporary world.

1 INTRODUCTION

Considering the high speed of the current technological evolution, it is quite a challenge for engineering professors and lectures to keep up dated with the latest technical development, especially for non-basic classes, usually faced by engineering courses. There is a consensus among educators and practitioners that engineering education must significantly change in order to support the current world's demands. Learning-by-doing can be one important concept to hold these new world requirements (Carlson and Sullivan 1999). An integrated laboratory for manufacturing education has been proposed by (Shiue et al 1999), to enable students for productive careers in industry by applying education with hand-on projects.

Connecting technical topics like manufacturing and design to others like management, process planning and costing analyses is another challenge for students. The influences in these fields are crucial for industry; however, students have struggled to realize this. It usually happens due to the lack of integration between the classes in under graduation degree. The current industrial world claims for it.

In order to improve the way of teaching, some proposals have been developed. (Meek et al 2003) implemented a methodology to integrate classes of the mechatronic under graduation at University of Utah. In this proposal, groups of students work for

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one year to develop robots which have to compete in a sport game such football, basket, and others. Wesselingh (2001) integrated some classes in a chemistry engineering course in order to develop a product made by students. Tolf et al (2003) present a methodology for integrating two engineering classes in order to solve project's flaws.

Hargrove (2002) integrates some disciplines of an engineering course to develop and construct a vehicle for manipulating blocks of raw material, aiming at following priorities: a) vehicle design, b) sensors for the raw block detection, c) capacity of choice, d) removing block approach.

Many authors discuss the lacks of engineering education for technical disciplines. Integration and relationship among groups is usually not mentioned. There is also lack of integration in technical and managing classes. According to Ziemian (2001), two key issues continue to warrant attention and improvement in engineering education:

a) Separation of the product design functions from manufacturing steps.
b) Misunderstanding of manufacturing process as an integrated system.

A network of different Computer Aided Systems (also known as CAx, i.e.: CAD, Computer Aided Design; CAE, Computer Aided Engineering; CAM, Computer Aided Manufacturing, and others) has been developed to support different tasks and occupational profiles, ranging from product development to manufacturing.

Dankwort et al (2004) discuss about 'CAx education'. According to the authors in the contemporary industry the product development can not seen on its own, as CAx and CAx education can not be considered stand-alone. Historically CAD was in the focus. Today, a network of CAx systems support quite different tasks in product development and manufacturing engineering. CAx education always has to be tailored to a specific group of person and/or jobs.

Many times engineers leave school knowing how to push buttons and icons of a commercial CAx software, but still don't know how to apply the CAx for aiding a whole manufacturing chain, and its integration with the diverse fabrication stages, through the integration of other CAx. They struggle to extract all potential that these technologies can offer. CAD is the most popular system in the CAx family. Although the CAD technology is well spread, the education of this subject at school still has a lack of efficiency (Ye 2004; Briggs 2001).

Having this general context of engineering education in mind a group of lecturers at Tupy Superior Institute - IST/SOCIESC, Brazil, has implemented an educational project in order to improve the mechanical engineering education at the college, focus on manufacturing plastic products, applying diverse CAx technologies. This educational project aims at integrating students and academic classes, joining technical and managing fields in order to close the manufacturing chain for a proposed plastic product.

Students from all different phases of the under graduation course are involved. The educational project consists in a 'Virtual Industry', which produces plastic products, accessing all the stages of this manufacturing chain, such as: market survey, product geometrical design, mold project, finite element analyses, manufacturing process, costs, production planning and industrial viability.

This educational project will allow students to get a better feel on the influences of different fields in engineering on the final product, considering costs, demand, information exchange during product development phase, and so on.

The current paper presents the proposed educational project, which has been propitiating a great improvement on the way of teaching engineering and attending to industrial demand.

2 DESCRIPTION OF THE EDUCATIONAL PROJECT

Academically the mechanical engineering under graduation offered by IST is divided into 6 (six) semesters, and was made to attend one of the most important industrial clusters for plastic and metal mechanic industry in Latin America, located in south of Brazil. Both sorts of industries, in this region, converging into plastic product development and molds manufacture. Figure 1 shows the main technical fields involved in manufacturing chain for mold and plastic transformation (Souza et al 2006).

Considering this atmosphere, the mechanical engineering course at IST purposes to make engineers who attend the regional demand for plastic and metal mechanic industry. The pedagogic project emphasizes the development of knowledge and abilities rooted in: product development, mold design, mold manufacturing, organization and managing, production planning, further ordinary skills. The activity intends to simulate an industry that produces plastic products. A group of students from each semester of the course runs one process involved in this manufacturing chain, as following:

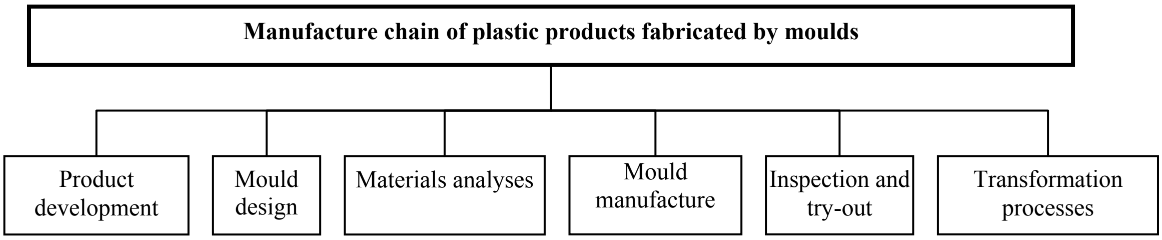

Figure 1: Manufactured chain focused (Sousa et al., 2006).

- Semester 1: Identifying products demands and specifications.
- Semester 2: Drawing the mold and product using CAD 2D software.
- Semester 3: Modeling the product and the respective mold by CAD 3D. Simulation analyses are also done by the students from this semester by using CAE software.
- Semester 4: Fabricating the mold by using a CAM software.
- Semester 5: Analyzing the cost of the product and the investment return based on the information got from the other semesters.
- Semester 6: Constructing the process planning for production the respective product, considering demand all characteristics involved.

Virtual Industry activity can implicates one or more disciplines from each of the 6 phases of the graduation course. Each phase represents one sector of the Virtual Industry. Thus, 6 industrial sectors compound the Virtual Industry and its manufacturing chain.

Considering the complexity and expenses of this chain, the tasks such as plastic transformation process; mold manufacture; and try-outs, cannot be accomplished. However, simulations of the manufacturing process are done by CAD/CAM/CAE systems, together to financial analyses.

2.1 Work Methodology

Each phase of the under graduation course represents one industrial sector; therefore the Virtual Industry has six sectors which represent its whole manufacturing chain. And in each phase of the under graduation course 8 (eight) teams are formed by students. Each group has about 4 (four) students. Therefore, there are 8 (eight) Virtual Industries running and each Virtual Industry has 6 (six) sectors, as presented in table 1.

The sector of the Virtual Industry has to network with one another in order to develop the proposed product.

During the team formation, lectures from respective classes are stimulated to look for individual student's abilities, considering three main characteristics: manager ship ability; communication ability; and technical ability. After that, the teacher has to form teams made up of: one chief manager; one communicator response; and students responsible for technical know how. The entire group is duly responsible for all assigned tasks.

The activity of the Virtual Industry starts with one product being produced. Each sector has to communicate with counterparts in order to obtain production information on the product, such as: geometrical data; manufacturing process; production management; individual costs; investment viability and others.

All the 8 (eight) Virtual Industries have to develop similar activities, considering the product to be manufactured, production batch and others. General variables along the development process can be defined by the team and explained in a final report.

In this activity a meeting is holding with lectures involved before the beginning of each school period. This meeting is used for set the dates and deliverables. Suggestions and improvements are suitably discussed.

2.2 Deliverables and Requirements

Each sector of the Virtual Industries has to generate and exchange information about its respective production activities. That information is divided in technical and management data. Technical data correlates mainly to:

- Product design, as geometry and special features.
- Design of the mold necessary for its production.
- Technical 2D draft for production line.
- NC programs for the mold manufacture.
- Analyses and simulations.

Software CAD/CAM/CAE are the most used tools in this stage.

Table 1: Manufacture sector of each Virtual Industry.

Phases of the course	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Industrial sector	**Marketing survey**	**Drafting department**	**Design department**	**Manufacture department**	**Financial department**	**Industrial department**
Phases of the course	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Industrial sector	**Marketing survey**	**Drafting department**	**Design department**	**Manufacture department**	**Financial department**	**Industrial department**

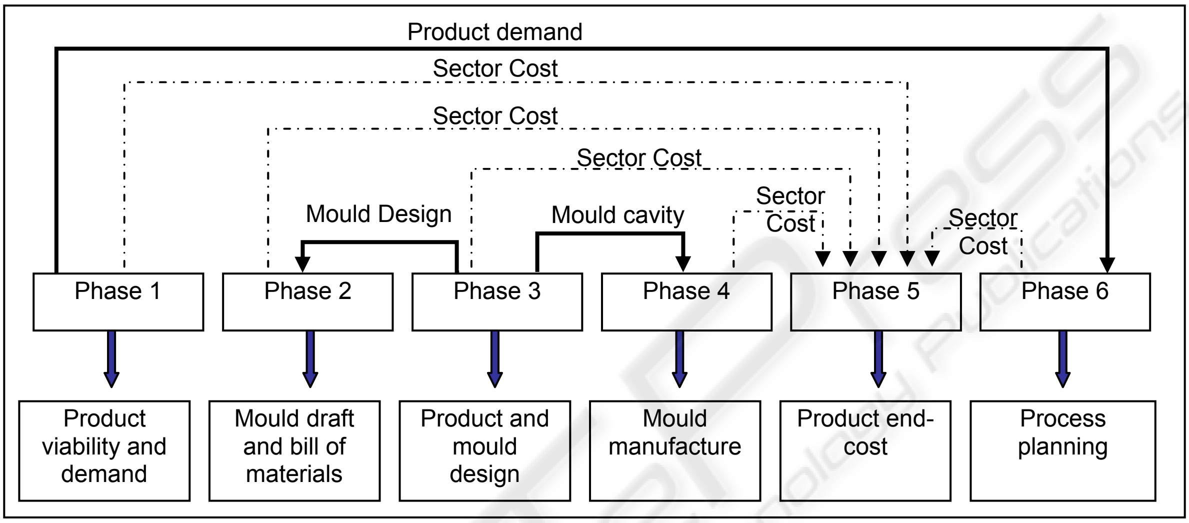

Figure 2: Flow of information, requirements, suppliers and deliverables from each phase.

Management data correlates mainly to:

- Market research and product definition.
- Demand forecast.
- Expenses in each phase to accomplish the related work, concerning: number of workers; labor costs and its legislative fees; computers and software requirements; direct cost of heavy machines, maintenance, equipment amortization and depreciation; staff training; raw material; and so on.

If convenient, students can also contract outside services. It must be listed in final report.

Many times, a specific sector requires information from the other sectors. Therefore, in order to complete the production cycle, all data involved must flow accordingly to its requirements. Figure 2 illustrates the requirements, suppliers and deliverables from each sector of the Virtual Industry. Virtual Industry activity takes up a full educational period. Students have to meet the whole team and exchange information regarding the project. E-mail is also used as an instrument for data exchange. Working in concurrent engineering technique is stimulated by the lecturers. A group which identifies and makes optimization along the process increases their final grade. Reports on the work flow have to be elaborated as well.

2.3 Activities Definition

For a first view, the project development can be summarized in: identify a plastic product to be manufactured; develop the mold required for its fabrication; fabricate the mold; production and financial analyses. The specific activity for each phase is related to the class on the respective phase. Table 2 presents the activities, the respective phase of the course and the classes correlated.

The activities are detailed as follows:

⬩ Activity 1 - Product definition: In order to be realizable, only one product is previously defined for the eight Virtual Industries. However, the details of this product are broken up into eight categories, for each industry, as following:

1-Product for men;
2-Product for women;
3-Product for both men and women;
4-Product for social class A;

Table 2: Activities of each phase representing the industrial sectors.

Activity	Activity definition and deliverables	Phase	Class
1	Product definition	1 and 3	Mold development
2	Mold design 3D modeling	3	Mold development. Computer Aided Design- CAD II
3	2D mold drafting and materials	2	Computer Aided Design- CAD I
4	Individual costs	1 to 6	-
5	Demand and product viability	1	Managing system
6	Manufacture of the mold	4	Computer aided manufacturing CAM
7	Product end-cost	5	Industrial cost
8	Production planning	6	Production Planning and control
9	Final presentation	1 to 6	-

5-Product for social class B;
6-Product for social class C;
7-Product for elderly;
8-Product for children.

The product geometry has to be modeled in a 3D CAD software (Unigraphics NX4). Students should concern about product ergonomic features and market acceptance.

⬩ Activity 2 - Mold design: Using the 3D CAD product modeled in activity 1, its injection mold has to be designed. The shrinking of plastic material, coolant system, injection points, pressure of injection, mold split line, the plastic flow analyses, and others project characteristics should be taken into account. The CAD is used to create the cavity of the molds and flow analyses are taken using the CAE software MoldFlow V5.

⬩ Activity 3 - Manufacture 2D draft and bill of materials: This phase of the course is starting knowing 2D mechanical drafts. They receive 3D CAD model and generates the 2D draft required to follow the production line on the shop-flour. They are also responsible for doing the bill of material required for the mold construction.

⬩ Activity 4 - Individual costs: All the phases have to understand very well all the costs involved in the related stage. The equipments, labor expenses, investments end so on. The costs of all phase are used to make the end-product cost.

⬩ Activity 5 - Demand and product viability: A market survey is done in order to estimate the product demand to aid the production planning ahead. The economical viability of the product is also checked.

⬩ Activity 6 - Manufacture of the mold: The fabrication of the mold by a CNC machine center is programmed. The students receive the 3D CAD geometry of the mold and generate the NC program using the Unigraphics NX 4 CAM module. They have to generate the NC programs and simulate the roughing, semi-finishing and finishing operation for manufacturing the mold. The time expend, the machine and the cutting tool used have to be defined by the group.

⬩ Activity 7 - Product end-cost: Using the cost information from all the phases, join information about the investments, returns expected, operation and commodity expenses, the product end-cost is defined.

⬩ Activity 8 - Production planning: The information about product demand together to the industry design is used to create a production planning.

⬩ Activity 9 - At the end of the academic semester, each team (Virtual Industry) has to present a report of the entire project and “release” its product. They have to present the project. Grades are given to compound the end-grade of each correlated discipline.

2.4 Schedule

The activity is taken along one educational semester – four months. Due to sort time, the complexity of the project, and the deep relationship among the phases to exchange data, the schedule should follow strictly as previewed. Otherwise, some correlated activities might not have sufficient time to accomplish its task. Table 3 illustrates the schedule.

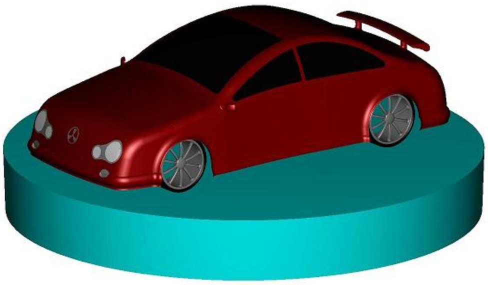

Fig. a. Product modeled in a 3D CAD

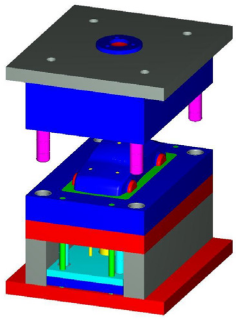

Fig. b. 3D mold design

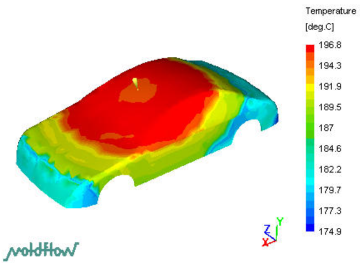

Fig. c.: Plastic flow analyses by CAE

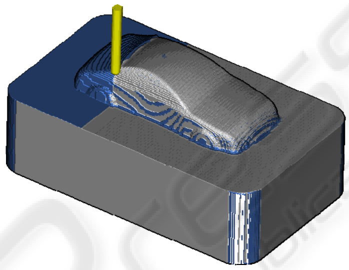

Fig. d. Mold manufacturing by CAM

Figure 3: Sample of project development by one of the Virtual Industries. Technical tasks.

Table 3: Project schedule.

Activity	**Schedule (Month)**			
	1	2	3	4
1				
2				
3				
4				
5				
6				
7				
8				
9				

3 RESULTS AND DISCUSSION

For illustrating propose, a product developed by one of the Virtual Industries has been chosen. Figure 3 presents the main results concerning technical issues, developed by the integration of students in phases 2, 3 and 4, of the graduation course.

One important result of the students' integration can be observed in this particular project. After the group in phase 3 modeled the product geometry, the group of manufacturers (phase 4) identified a geometrical limitation. The product had a fillet radius of 2 mm which could be very hard to manufacture. So the group decides to modify the fillet radius to a reasonable value for manufacturing, 5 mm.

Table 4 presents the main data developed for management tasks, involving students from Phase number 1, 5 and 6 of the engineering graduation. Besides the usual management, costs, and process planning information, the students had the possibility to amplify their feel considering information gathered from all manufacturing chain, which would have been difficult to get without this project.

In order to have a feedback about the proposed method of teaching, a simple questionnaire was completed by the students after the graduation course. Grades from 0 to 6 (6 is the best great) show the students' view about this activity, in a general context, as presented by Figure 4.

Besides, the proposed method influences the teaching methodology due to drive the lectures to enclose their subjects to the industrial application and improve the students' concept of working in a team. However the project acceptance is a challenge for the leaders, to make lectures and students aware how vital their involvement are for the project to keep going on.

Table 4: Sample of production and cost definition development by one of the virtual industries.

Production			*Cost-Volume-Profit Analysis*	
Monthly production (unit)	*35.000*		*Cost-Volume-Profit Analysis*	*1,40*
Year production (unit)	*420.000*		*Variable cost ($/unit)*	*0,25*
Cost production ($/unit)	*1,17*		*Month fixed cost ($)*	*32.039,9*
Mark Up-20% ($/unit)	*1,40*		*CM - Contribution margin ($/unit)*	*1,15*
**taxes -33,25%($/unit)*	*0,47*		*CM (%)*	*115%*
Selling price (unit)	*1,86*		*Countable break-even point (unit/month)*	*27.915*
Monthly production (unit)	*35.000*		***Economic break-even point (unit/month)*	*37.464*
Year production (unit)	*420.000*		*Financial break-even point (unit/month)*	*26.011*
Financial analysis			**Period/Investment**	-415.000,00
Annual net income	675.813,60		1 yr.	228.457,56
Fixed costs	384.479,88		2 yr.	228.457,56
Variables costs	105.600,00		3 yr.	228.457,56
Gross profit	185.733,72		4 yr.	228.457,56
Depreciation	83.039,88		5 yr.	228.457,56
pre-tax profit	268.773,60		6 yr.	228.457,56
Income taxes (15%)	40.316,04		7 yr.	228.457,56
Net profit	228.457,56		8 yr.	228.457,56
Incomes	228.457,56		9 yr.	228.457,56
			10 yr.	228.457,56
			Present value	1403773
			Net present value	988773
			Internal rate return	1
			Value	160918
			Payback=Period	2

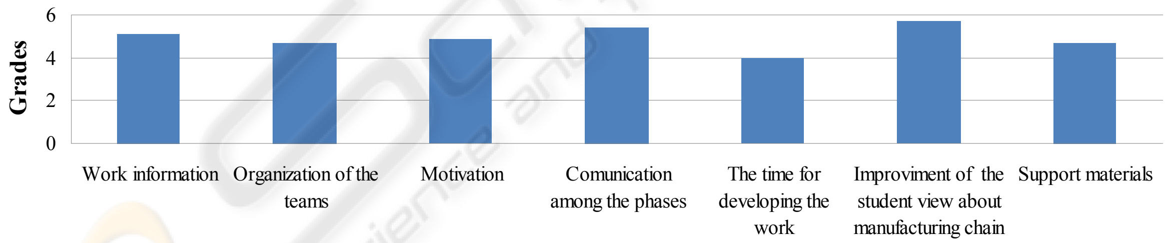

Figure 4: An average evaluation of the proposed method from the students' point of view.

4 CONCLUSIONS

The proposed approach to teaching engineering has been proved to be adequate to enhance the students' learning, besides technical and scientific, knowledge about management, human behavior, network and teams spirit, getting the filling about the real industry atmosphere.

This interdisciplinary educational activity allows future engineers feel the importance of the integrating different stages of a manufacture chain and how the concurrent engineering could help the processes, improving product cycle development. It also propitiates students a holistical overview on the whole cycle of product development, management and economical issues, technical problems and the impact of each manufacturing stage on the end-product.

This activity promotes a personal growth for the students, once they have experienced how to work in a work team. They have to manage conflicts, capacity and limitation according to different way of thinking. The students' motivation on this work could be observed when the students put in extra time to develop a project in which they believe to be worthwhile.

Before this methodology was implemented, many times students finished the course knowing quite well strict subjects. However, they are not aware of all the others issues surrounding the subject, such as cost involved in each industrial sector, production time, the relation with other sectors, and the problems that might arise in a real application. The activity also improves students' feel on how all product data can influence the whole manufacturing process.

The main difficulties and challenges to be overcome are:

- Make lectures fully aware how vital their involvement is for the project to keep going on.
- The time table is very strict. Each and every phase depends on one another.
- Any phase not well carried-out can bring setbacks and failure to the project.

Even with the above difficulties this approach to teach engineering motivates students, avoiding teaching-learning fragmentation and has duly proved its potential.

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REFERENCE

Carlson, L. E.; Sullivan, J. F. (1999). Hands-on Engineering: Learning by doing in the Integrated Teaching and Learning Program. Int. J. Engng. Ed. Vol 15, N1, 20-31.

Shiue, Y.; Beard, B. B.; Santi, M.; Beaini, J. E., Integrated Laboratory for Manufacturing Education. (1999). Int. J. Engng. Ed. Vol 15, N1, 51-57.

Meek, S.; FIEL, S.; Devasia, S. (2003). Mechatronics education in the Department of Mechanical Engineering at the University of Utah. Mecharonics, 13, 1-11.

Wesselingh, J. A. (2001).Structuring of products and education of product engineers. Power technology, 119, 2-8.

Toft, Y.; Howard, P.; Jorgensen D. (2003). Human-centred engineers- a model for holistic interdisciplinary communication and professional practice. International Journal of Industrial Ergonomics, 31, 195-202.

Hargrove, J. B. (2002). Curriculum, equipment and student project outcomes for mechatronics education in the core mechanical engineering program at Kettering University. Mechatronics, 12, 343-356.

Ziemian, C. W. (2001). A System Approach to Manufacturing as Implemented with a Mechanical Engineering Curriculum. Int. J. Engng. Ed. Vol 17, N6, 558-568.

Souza, A. F, Sacchelli, C. M.; Scalice, R. K.; Gilapa, L.; Lacerda, M. M. (2006). Management Analyzes of Production of Injection Molds. IV Mechanical Enginnering Congress. Recife-PE, Br.

Dankwort, C. W.; Weidlich, R.; Guenther, B.; Blaurock, J. E. (2004). Engineers' CAx Education - it's not only CAD. Computer-Aided Design, 36, 1439-1450.

Ye, X.; Peng, W.; Chen, Z.; Cai, Y. (2004). Today's students, tomorrow's engineers: an industrial perspective on CAD education. Computer-Aided design, 36, 1451-1460.

Briggs, C. (2001). On the role of CAx in Design Education. Int. J. Engng. Ed. Vol 17, N4-5,455-459.