Application in integrated mechanical design: A concurrent engineering project

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Abstract

This work presents a new educational application of integrated mechanical design. The main goal was the industrialization of a product by a team of technician students from the *Institut Universitaire de Technologie de Nantes*/IUT (France) with a student engineer[1] from the *École Centrale Nantes*/ECN (France) acting as the project manager.

Development in this project began with the product specifications and continued through testing of different prototypes. The students from the two schools were required to plan, organize, exchange, communicate, search and validate using the Concurrent Engineering organization and new tools of communications. The subject product was a new "all-terrain in-line roller" for a French sport equipment manufacturer.

During this project, several "new" tools of communication; E-mails, ftp, web, chat, white board, exchange files and Visio-communications were tested. The development team analyzed the reliability, relevancy and performance of these tools for teaching product design.

This industrialization project has been a great technological, pedagogical and human experience for the students in an industrial environment as well as for the teachers testing new tools for communication and learning in a design and manufacturing application.

Based on the results presented in this paper, we are now preparing a project for the next university session with a new partner: École Polytechnique de Montréal. Our intention is to conduct an experiment on a subject in the design group using new communication and Product Data Management tools. For this case the different technological cultures, teaching organizations and time zone considerations will be taken into account.

Key words: integrated mechanical design, concurrent engineering, international design project.

[1] In France, university level college for the continuing education of qualified engineers

1 Introduction

Many experiments are currently underway to evaluate the influence of the use of technology information and multimedia for teaching various subjects in mechanical engineering.

We tend to agree with authors M. Kadiyala and B.L. Crynes [6] that there are important advantages to be gained using these technologies both from an efficiency point of view and by capitalizing on opportunities they provide for innovation.

These technologies have been applied in various courses in the Design and Manufacturing departments. As they learn manufacturing processes, for example, the students must acquire a good understanding of theories related to strength of materials, heat transfer, material structure, etc. Manufacturing processes are often very complex and difficult to explain and therefore numerous lab sessions are typically included in the course curriculum. The labs are expensive, long to prepare and their efficiency is sometimes affected by the influence of parasitic phenomena that makes it difficult to interpret the results. A similar problem is inherent when films are used due to the fact that it is impossible to separate the different phenomena that must be demonstrated and understood. The limitations of these teaching methods can be overcome through use of computer animations and simulations, which allow the processes of interest to be isolated and presented individually.

A number of computer simulations and animations have been realized and applied to explain typical manufacturing problems during the Advanced Manufacturing course given in our universities. The slides shown during this course (those already containing short movies) have been enhanced with animations and simulations. Similar animation and simulation tools are used in Design courses.

It is important that students in Mechanical Engineering work in real industrial applications to effectively learn the concepts taught in our design and manufacturing curriculum. For the teaching of Design, CAD systems are currently used in courses and exercises. Students are required to complete practical projects either on their own or in teams. We think that working in teams prepares them well for their future positions in an organization.

Team members are not always seated in close proximity. Presentation tools such as CAD drawing files, animations and simulations must work hand in hand with transmission tools such as E-mail, ftp, visio-communication and exchange files. Integration of these technologies to allow for development activities among team members located at a distance from one another without need for displacement was one of the challenges explored during this project.

Design teaching with concurrent engineering projects was introduced during this study to different student teams. Our objective was to improve the relationship between our Design teaching practices and the ‘real-world’ industrial context.

2 First Project in integrated design

2.1 The pedagogical approach using industrial projects

The establishments of Nantes that created this project have always persisted in providing opportunities to enrich the pedagogical content of their design and manufacturing courses using industrial projects that can be completed by student teams.

For the Mechanical Engineering department of the *Institut Universitaire de Technologie de Nantes*, this educational practice is as follows:

· 12 to 15 projects yearly,
· A team of 5 to 9 students for each project,
· 8 consecutive hours weekly devoted to these projects; from October to February for design and mock up, and February to June for the final prototype,
· The subjects are varied
· Per year, 3 to 5 tons of transformed materials, 50 gigabytes of CAD and CAM file data and business figures of 0,5 MUS$

In the program of the *Ecole Centrale Nantes,* project specification is introduced during the first year. The objectives of this first project are:

· Expose students to the industrial dimension of their schooling
· Put them in situations where they are in direct contact with an industrial case
· Confront them with the interpersonal challenges encountered when working in different teams
· Meet specified dead lines
· Consider costs

40 project subjects are submitted by local industries each year. Each project is completed during 22.5 hours spread over a four month period. Three teachers look after administration of the student groups. The students are placed in groups of six. Each of these groups is led by a teacher from the school. An oral presentation of the project takes place at the beginning of 2nd year with the participation of the client.

Second year students in the Mechanical Engineering department developed the notion of pedagogical activity in teams in the form of a design and manufacturing project. This group project to design and manufacture a product is rich in learning opportunities because of the hands-on manufacturing experience the students receive.

In the third year, this project becomes more "transverse" than in second year. It consists of demonstrating the transverse approach of the engineer’s function to the students during the product design stage. The six members of the student groups must organize the division of work tasks among themselves.

2.2 Birth of the project

2.2.1 Educational orientation

Projects submitted for student groups generally center on the development of unique prototypical machines built using conventional machining processes. The idea for the project presented in this article consisted of students going beyond prior project standards into the manufacturing and mass production phases of product development.

Further to this idea, it was proposed that an engineering student from the *École Centrale Nantes* be the design project leader who would manage a group of six technician students from the *Institut Universitaire de Technologie de Nantes*.

In order to bring this project to fruition, we needed to find the subject of the product design.

2.2.2 The support

Jean-Pierre Lévy, sport teacher, conceived and constructed an artful pair of all-terrain in-line rollers in the 1980's. This innovation was ahead of its time however, and the commercialization of his new product did not occur until a few years ago. M. Lévy asked the *Institut Universitaire de Technologie de Nantes* to develop his idea.

Our new educational approach was applied to encourage students in a design and manufacturing project based on the creation of an all-terrain in-line roller for average consumers.

2.2.3 Pedagogical organization

In order to construct a successful project one of the challenges was the integration of two different educational planning structures: The *Institut Universitaire de Technologie de Nantes* students worked 8 hrs per week with their instructors while the *École Centrale Nantes* student had an annual block of 125 hrs.

It was decided that:

- One student from the *École Centrale Nantes* would act as the project manager
- Six students from the *Institut Universitaire de Technologie de Nantes* would participate as design technicians, mock up and prototype builders.
- The teachers would have the role of graders/evaluators and judge the pertinence of the solutions and chosen approaches. They would also serve as consultants/experts in specific areas and therefore be available to the students charged with managing the material and human resources.

2.2.4 Pedagogical structure

The *Institut Universitaire de Technologie de Nantes* and the *École Centrale Nantes* are the principal supporters of the *Atelier Inter-établissement de Productique de Nantes* (AIP).

Our Ministry and its Regional Council finance the AIP. It consists of an experimental workshop and a computer center (CAD/CAM, CA Production Management, Vision Systems, Image Processing, etc.). The AIP provides the framework for experimental training in automation and production through a number of practical classes and industrial projects which are usually carried out in collaboration with individual companies.

The AIP was established for research projects which are of an industrial nature. The varied equipment at this workshop can be used either separately or together as it is interconnected within integrated units. It was decided to use the AIP workshop equipment for our design project.

2.3 Technical and data processing mediums

Technical and data processing mediums at our disposal during this project were:
- Design, manufacture and project management software
- Telecommuting and communications software

2.3.1 Design, manufacture and project management software

The design and manufacture tools available are well known in the Mechanical engineering field:
- CAD and CADCAM: ProEngineer, Autocad Mechanical Desktop, SDS, Visi-Cam, Goélan and the drawing board
- Project management: Cdcf, MS Project
- Machine tools with numerical control: Lathe, Milling center, EDM, HSM Centers etc.

2.3.2 Telecommuting and communications software

The fact that this industrialization project was run from 2 distinct sites provided opportunities for experimentation using telecommuting tools and communication through multi-media and technical data exchanges.

The AIP was a partner of both the École Centrale Nantes and the IUT de Nantes and therefore became the natural resource for the installation of these communication tools. Several types of tools were set up:
- Traditional tools: telephone, telefax,
- Internet «tools »: email, FTP site, Web site …
- Tools for video-communication and sharing of applications

Traditional tools allow the students to communicate easily to potential subcontractors for research of solutions or requests for quotations.

The Internet tools, in particular electronic mail, promote exchanges between those who must be in regular contact during the course of the project. The intention is to generate asynchronous co-operation; the players interact on their tasks by exchanging the data but without co-temporality. Web access promoted research of components, of solutions, subcontractors or benchmarking. An FTP site was set up to exchange files in a context where the information processing systems of the 2 sites were disparate. It should be noted that this service was rarely used, students preferred to exchange through file attachments on electronic mail.

Videoconference tools consisted of visio-communication with white board and share of applications. These processes, contrary to the electronic mail or FTP service, are described as synchronous.

Visio-communication:

Visio-communication allows the transmission of video and voice and therefore constitutes a direct means of communication between distant speakers. Moreover, it allows participants to work jointly on multi-media documents using a shared white board. This is represented by pages that can be prepared in advance and then be annotated interactively by each person in the videoconference. Indeed, those present at these meetings see the same screen at the same time and can modify on-line the proposals of the speaker(s). With these tools one can also exchange electronic files.

Share of applications:

Share of applications is a function that allows distant speakers to each have, in turn, control of an application (CAD software, CADCAM, project management, spreadsheet, word processing, etc.) that is running on a single machine. Each person attending the meeting sees the same screen at the same time and can propose and remotely demonstrate modifications to the shared document.

The materials unit and software setup:

The selected unit ran on local area networks, Internet or ISDN. ISDN operation allows a guaranteed bandwidth and thus makes the use of visio-communication attractive due to fast data transmission. It also works in videoconference bi-point. Each site was equipped with a PC Pentium containing a videoconference kit (Proshare INTEL kit approximately: 5000 FF/890 US$. 1 hour of point-to-point videoconference on ISDN in local zone: 30 FF/5.40 US$, in widened zone: 140 FF/25 US$). The Standards used were H320, H323 and T120.

Contributions of video-communication and share of applications:

Students used all of the tools available to them within the framework of the project. Those particularly useful were:

- Visualization of prototypes with the camera,
- Share of CAD applications, project management,
- File transfer.

These tools of visio-communication are easy to implement and reasonably priced. They allow companies to "reduce" the distances between sites and avoid displacements. This capability lowers costs and increases the reactivity of decision-making.

2.4 Development of the project

2.4.1 Planning and organization

Each year the project leader (student) consulted with all the members of the project team to define a proposal for the organization of the group and a plan of activities. This specified, among other things, the methods of exchange (frequencies, means, and locations) and a schedule for project reviews, the various group meetings and meetings with the partners. Ensuring the dynamics of the organization was the role of the project leader who coordinated, validated, reorganized, and updated the plan as necessary.

2.4.2 Need and market research

It was necessary to undertake a study, which was updated each year, in order to define the details of the project scope. Companies specialized in sporting products were contacted along with users' associations. An investigation of future users was carried out. Meetings between suppliers and subcontractors were organized. Through analysis of the information gained during this study we were able to determine the profile of the standard user, the product cost, its life cycle and the required rate of production.

2.4.3 Product specifications

Development of product specifications was carried out and formalized in order to generate the most precise data, while at the same time maintaining a high degree of flexibility.

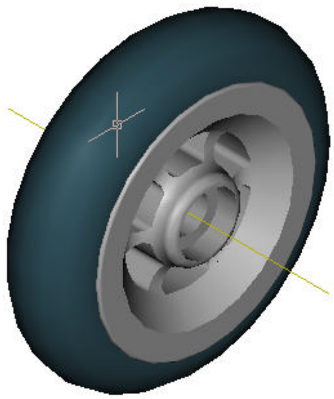
2.4.4 Search for information

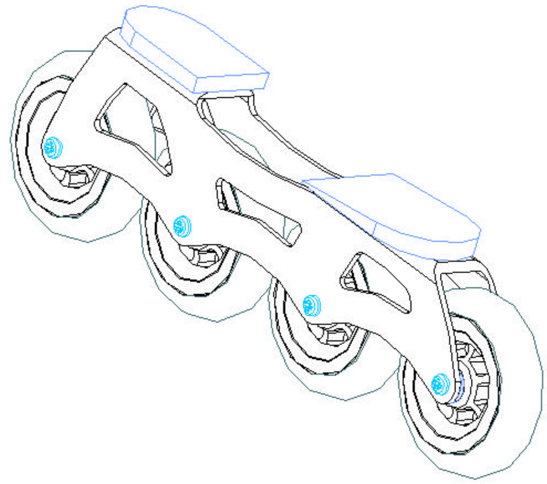
This step was not limited to information related to the specific field of in-line rollers. The search covered a broader scope in order to be able to dynamically respond to the evolution of the project and in particular to keep in step with industrialization and the capabilities of potential subcontractors (suppliers of raw material, production techniques, mechanical components, standard elements, etc.).

2.4.5 Study, design and development of the prototypes

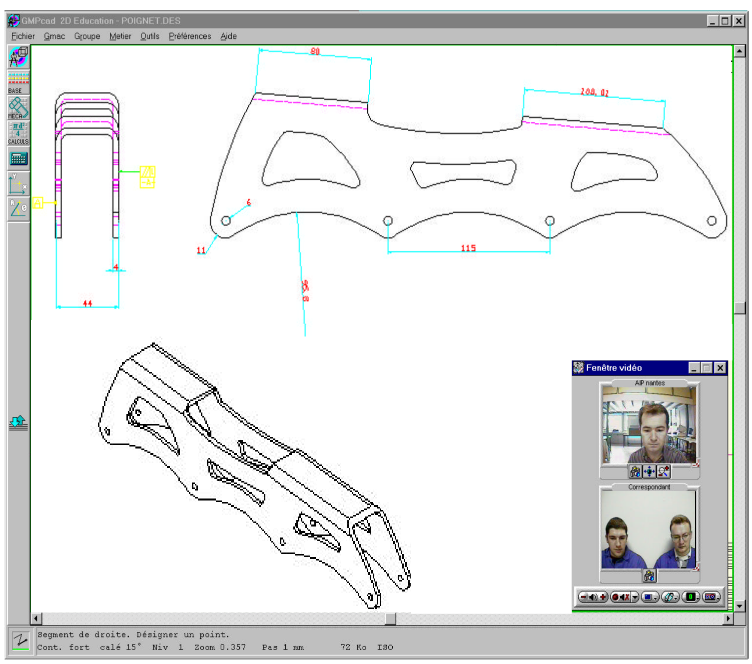
Various tasks involved in study, design and development were not carried out sequentially, but rather in parallel according to our progress and the results obtained. This part of the project was carried out over three years. The information presented here is a brief summary of these activities. The first prototypes:

The project was divided into two main elements, the wheels and platen.





Visio-communication and shared documentation during design:



2.4.6 Industrialization and marketing

Industrial production of the in-line roller was one of our principal considerations throughout the project. A number of challenges were faced, particularly for the manufacture of the component providing the wheel-to-ground contact.

The final project (2001) is presented in this section. We continue to maintain a list of contacts established during the project for possible partnerships in the development of this product.

The all-terrain in-line roller:

2.5 Analysis and the assessment of this new teaching approach

This new teaching approach was very enriching and allowed us to achieve the following objectives:

- To bring together two establishments in the same field, Mechanical Engineering and Computer Integrated Manufacturing, even though these are taught on different levels in the respective locations,
- To test new ideas for teaching
- To put a young engineer, nearing the end of his formal education, in a real industrial situation
- To place a team of skilled technicians under the coordination of a student engineer,
- To bring together and test an infrastructure of materials and software based on new tools of communication and data exchange.

Some of the tools in the infrastructure provided for this project were absolutely essential, while others were not used on a frequent basis. Several trends were observed:

- After a period of the discovery of the "new" videoconference tool, the time period between consecutive uses increased more and more,
- The distance between the two sites IUT and ECN (approximately 6 km) was not dissuasive enough to prevent the displacement of the students, who tended to travel between these locations by car.
- The tools were installed in rooms located far away from the Design offices. This did not facilitate their availability, flexibility and reactivity for the students,
- The students did not receive enough training on these new tools during the assigned time of the project. Instead, they preferred to look into the technical problems of industrialization of the product.

The results of experimentation that took place during this project were used to classify Internet services related to co-operative work into 3 categories. These ratings from 1 to 3 used the following convention:

1 –Essential, must be provided as a high priority
2 –Useful, a real utility for this project
3 –Not useful for the project studied

Internet Services	Group project rating
Electronic mail	1
FTP	2
Web	1
Videoconference: Audio and video Point-to-point	1
Videoconference: Audio and video multipoints	2
Videoconference: Chat or talk	3
Videoconference: White Board	2
Videoconference: Share of applications	1
Mailing list	2
Forum of discussion	3
Other services:	
High speed Internet connection	1
Workflow Software	3
Groupware Software or «TEAM Work »	1

The development of this all-terrain in-line roller was an extremely interesting project, enriching for all team members, the students of the IUT and the ECN, and other personnel from both institutions who became involved in this endeavour.

We wish to continue to test this co-operative project approach; delocalized with remote communication, as applied to the case of industrialization.

3 A new concurrent engineering project

Based on the experience of the first project, we propose a new International concurrent engineering project with a team composed of students from different universities. The members of the project team will be arranged in the following 3 sub-groups:

- One student from the *École Centrale Nantes* /France acting as the project manager
- Five students from the *École Polytechnique de Montréal* /Canada as design engineers
- Six students from the *Institut Universitaire de Technologie de Nantes /France* as design technicians, mock up and prototype builders.

3.1 Organization and Planning

One of the major challenges will be the combination of different technological cultures, the different teaching organizations and the lag between the respective time zones.

In order to meet these challenges we decided to attribute specific hours to each student group. Two times per week, the morning will be given to the Canadian students and the afternoon to the French students in order to compensate for the 6 hour time difference.

The project will begin in September 2002 with the 3 sub-groups. These sub-groups will work together to form a unique project team.

In mid-December the project team will finish and present a virtual mock up of the product during a global meeting. This public web-meeting will be made accessible so that other students from the 3 schools (or from other universities) can follow the proceedings.

At the beginning of January 2003, the first real mock-ups will be fabricated with machining equipment at IUT and ECN. The first mock-ups will be sent to Montreal so that initial testing can be performed at *Ecole Polytechnique*.

Changes and evolutions in the design will be generated once the test results are compiled and analyzed. These changes will be introduced using the CADCAM system.

Several series of alterations will be necessary in order to perfect the design to meet the product specifications. The students must keep in mind that this is an industrial project and therefore economic considerations as well as manufacturing efficiency are critical concerns.

The project will be completed by June 2003.

3.2 Telecommuting and communications

The reliability, relevancy and performance of E-mails, ftp, web, chat, white board, exchange files and visio-communications have been analyzed during the first project as summarized in the previous sections of this report.

During this International design project, some new tools for communication, planning and Product Data Management will be studied. An example is the webCT computer product, which makes it possible to mix and exchange, using the same structure, all the created design and manufacturing data, to organize tasks and to stock all recorded calls or e-mails.

3.3 The subject of the new design project

Pratt&Whitney Canada have expressed an interest in collaborating with us for this International project and are in the process of gathering potential subjects. An example of a potential subject is the re-engineering of an air-oil separator for plane engines.

4 Conclusion

We are convinced that the new international project will be an educational experience even more enriching than the in-line roller development from both a technical and humanistic standpoint.

Specific tools will be developed for use by the student team members during the new project, using webCT to mix E-mails, ftp, web, chat, white board, exchange files and visio-communications. Results of experiences using these new communication and project tools will be analyzed and exchanged.

Finally, we are sure that these projects constitute an advanced means for achieving a higher academic excellence of engineering students. We hope to provide evidence of this fact through superior performance parameters.

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Richard Gizicki – Staff Design Engineer – Pratt&Whitney Canada

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