International Journal of Engineering Education Vol. 27, No. 3, pp. 488–497, 2011
Printed in Great Britain
0949-149X/91 $3.00+0.00

Learning Through Play in a Final Year Subject: Enjoyable Design Experience for Teaching Product Development*

ANDRÉS DÍAZ LANTADA, PILAR LAFONT MORGADO, JUAN MANUEL MUNOZ-GUIJOSA, JAVIER ECHÁVARRI OTERO AND JOSÉ LUIS MUÑOZ SANZ
División de Ingeniería de Máquinas—Innovative Teaching Group on Machines Engineering, Universidad Politécnica de Madrid (UPM), c/ José Gutiérrez Abascal 2, 28006, Madrid, Spain. E-mail: adiaz@etsii.upm.es

In recent years educational gaming has been progressively perceived as a very effective tool for improving teaching-learning activities in higher education. The use of such play-based methodologies for engineering education can promote several practical and communication skills of great value for students' future professional development. At the same time it greatly helps to motivate students and make them more aware of their own capabilities and the learning process.

This paper details the application of a play-based methodology for improving students' results and motivation in the subject 'Development of Plastic Products'. The active learning strategy consists in assigning student groups different toy development tasks, so that they can apply the design concepts learned and present their results in public. It is thereby hoped to promote a set of abilities that are ever increasingly valued in the industrial and business world, such as teamwork, creativity and communications skills.

Results have been compared with experiences from previous years, linked to the development of conventional products. The results show that carrying out a monographic experience on 'Toy—Design' has promoted students' satisfaction, motivation and results. Some ideas for future improvements, mainly based on students' opinions, are also discussed.

Keywords: learning through play; active learning; motivating students; CAD-CAM-CAE tools; rapid prototyping technologies

1. Introduction

The subject 'Design and Manufacture with Plastic Materials', taught in the 5th course at Universidad Politécnica de Madrid (UPM) as part of the Mechanical Engineering Degree, has been designed to fit in with the trends towards educational innovation and active learning set out within the framework for implementing the European Higher Education Area (E.H.E.A.) [1] following the purposes of the Bologna Process.

With this process implementation, higher education systems in European countries should be organised in such a way that:

- It is should be easy to move from one country to the other (within the European Higher Education Area) for the purpose of further study or employment.
- The attractiveness of European higher education is increased so that many people from non-European countries should also come to study and/or work in Europe.
- The European Higher Education Area should provide Europe with a broad, high quality and advanced knowledge base, ensuring the further development of Europe as a stable, peaceful and tolerant community benefiting from a cutting edge European Research Area.

The active learning strategy proposed in our subject consists in assigning groups of students different product development tasks, so that they can apply the design concepts learned to real problems, and then present their results to their fellow students'. It is thereby hoped to promote a set of abilities that are ever increasingly valued in the industrial and business world, such as teamwork, creativity and communications skills (ABET Professional Skills) [2].

The tasks begin with an analysis of existing products and end with the production of prototypes. This means that the new Rapid Prototyping Technologies [3] available in the UPM's 'Product Development Laboratory' can be applied for teaching purposes, thereby implementing a teaching-learning method that at all times promotes active student participation.

The most important educational innovation objectives of this experience are:

- To enable students to experience a complete product development, from the conceptual design stage up to carrying out tests on a physical prototype.
- To follow the stages really used in industry, when it comes to designing and manufacturing new products.
- To encourage students to participate actively in their own learning process.

* Accepted 15 October 2010.

- To emphasise the importance of teamwork and finding solutions reached together.
- To continually induce students the use of critical thinking as essential tool for solving problems.

During course 2008–2009 the development experience was focused on 'Toy design', as a way for improving student's motivation and results through play-based activities. Below are explained the tools used and methodology followed for supplementing the teaching of theory with the development of applied tasks, together with the results of this teaching experience.

2. Supporting tools and technologies used

The use of 'CAD-CAM-CAE' tools (computer aided design, manufacturing and engineering tools) is essential in any industrial machine or new product development process. The experience described has a highly praiseworthy teaching aim since it motivates students to use the different design and calculating tools used in mechanical engineering available in the Machine Engineering Division of the UPM, such as:

- CAD programs (Solid Edge, Catia, Inventor, Rhino, Solid Works), for modelling the different parts of a machine in 3D and obtaining the files needed to manufacture rapid prototypes.
- CAE programs (Solid Edge, NX-6 Siemens), to undertake the simulations of kinematic function. In order to check both the parts design and the appropriate selection of materials, programs for finite-element calculation are also used (ANSYS, NX-6 Siemens, I-DEAS, Moldflow Part Adviser, Abaqus).
- CAM programs (Catia, Moldflow Mold Adviser), in manufacturing simulations and mould development for thermoplastic materials injection.

The Machine Engineering Division also places various 'Rapid Prototyping Technologies' at the students' disposal, so that they can materialise their designs through the manufacture of prototypes for design validation, particularly:

Laser stereolithography—A technology based on the possibility to activate a polymerisation reaction in an epoxy resin in a liquid state by projecting a laser beam, its power and frequency having been adapted to the type of resin. The laser gradually 'draws' layers on the surface of the liquid resin, following a path marked out by the CAD 3D file containing the part geometry. The monomers in a liquid state, on being exposed to ultraviolet radiation polymerise and become solid. The operation is repeated until the end part has been obtained in epoxy resin by the successive superimposing of polymerised layers (Fig. 1). The parts obtained by this process are particularly suitable for checking the parts visually and for size.

Vacuum casting in silicone moulds—The initial models or stereolithography parts can also be used for obtaining flexible silicon moulds which are subsequently used to obtain polyurethane resin replicas that are more resistant and suitable for working trials. These resins reproduce the mould cavities with great precision thereby obtaining working prototypes in materials similar to those of production.

These technologies serve to complement the 'CAD-CAM-CAE' tools, enabling physical parts to be obtained in a few days, directly from designs carried out with the aid of a computer. Design iterations can be reduced and optimised, and therefore, production start-up accelerated, which means these technologies are highly valued in industry and so are very positive for training students.

This use of rapid prototyping technologies as a teaching aid is of recent appearance. Among some of the most innovative experiments it is worth highlighting those carried out in technical schools such as the 'Massachusetts Institute of Technology' [4], the 'Western Washington University' [5], the 'Rose-

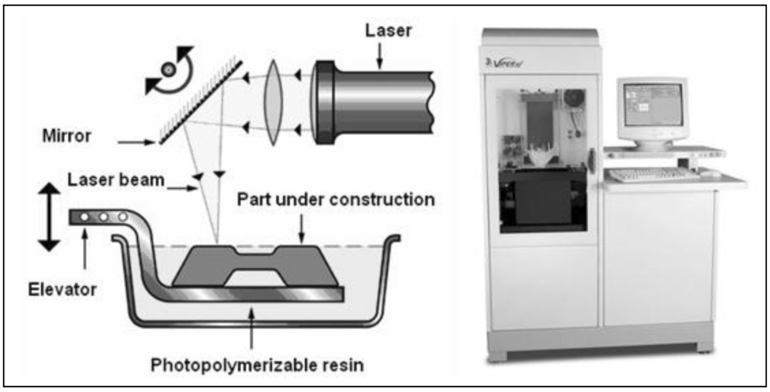

Fig. 1. Stereolithography process and machine example.

Hulman Institute of Technology' [6], the 'Massey University' [7], the 'Universidad Simón Bolivar' [8] and the 'Universidad Politécnica de Madrid' [9–10].

In all of these schools, students have experienced the different product development stages: conception, design, simulation, analysis, manufacturing and tests, using tools such as Mechanical Computer Aided Engineering ('MCAE') and the most recent Rapid Prototyping and Manufacturing Technologies ('RP&M').

The application of these computer aided design, engineering and manufacturing technologies to teaching the subject 'Design and Manufacturing with Polymers' during course 2008–2009, supporting the already mentioned 'Toy Design Experience', is explained below.

3. Teaching learning methodology

At the beginning of the subject, the students are divided into teams of three (exceptionally four), which are given different products to be developed. Products are chosen that can be mass produced by thermoplastic materials injection and which allow the knowledge acquired in theory classes to be developed in a practical way.

During the 2008–2009 academic course, a total of 71 students have approached the complete development of 23 different products. To promote motivation among students the experience was centered in toy designing and each group should find and design a different toy.

Studies do not include steel mould manufacture or injection machine tests due to the high investment costs and the time that would be involved. However, all injection simulations performed using 'Moldflow' type programmes are very positively assessed. The stages that must be got through by students are enumerated below and are those corresponding to the development of a new industrial product [11], all of which helps to give a boost to the teaching aims proposed:

- Approaching the problem and analysing the specifications.
- Conceptual design and choosing materials and components.
- Detailed design, including explanation of calculations.
- Solution analysis and mould filling simulations.
- Prototype manufacture.
- Assembly and working trials.
- Verifying results and drawing up conclusions.
- Comparing and evaluating results.

3.1 Approaching the problem

The students gather information on their products and analyse existing solutions together as a prior stage to the design tasks. In any development process an exhaustive information search needs to be done on the product, and a comparison made between similar solutions that exist, in order to be able to prepare an appropriate planning schedule and fully and exactly define the aims. The result of all this will be a list of requisites with the basic information for the project (desired toy to be designed). At every instant students must endeavour to comply with these basic specifications (or mandatory requirements). Moreover, it is important to make a list of pretensions (or requirements to be taken into consideration whenever possible) that will form a basis of negotiation with the client and increase competitiveness and profits.

3.2 Conceptual design

The teams continue to work on the list of requirements to identify any crucial problems and choose the best solution for each one, paying also attention to manufacturability, time optimization and costs reduction.

Using CAD programs and drawing sketches by hand (as shown below) sees the beginning of the work to obtain a pre-design of the different parts while comparing any possible alternatives. In this way, materials are chosen according to the initial estimations of resistance needed for the different components and parts. Fig. 2 shows as example the conceptual design.

3.3 Detailed design

Once the most appropriate solution has been chosen from the different pre-designs, the different parts must be exactly defined. Following the concepts explained in the theory classes, the students must use a design approach oriented towards manufacture and assembly, in line with the current trends in Concurrent Engineering. The results of some different tasks are shown below in Fig. 3.

To check that the chosen materials are suitable, the estimates need to be compared, using simplified theoretical models, with the information provided by Computer Aided Engineering programs. The use of thermoplastic material injection simulation programs, which are habitually used prior to the construction of the moulds, is also important, in order to check that the choice of materials and injection conditions are appropriate, as well as an optimum distribution of the cavities in the mould, material inlets, filling channels and cooling system.

The teaching aim is worth emphasising, since it motivates students to use the different computer design and calculation tools used in mechanical engineering, as explained above. The basic concepts for employing CAD Tools are explained in previous

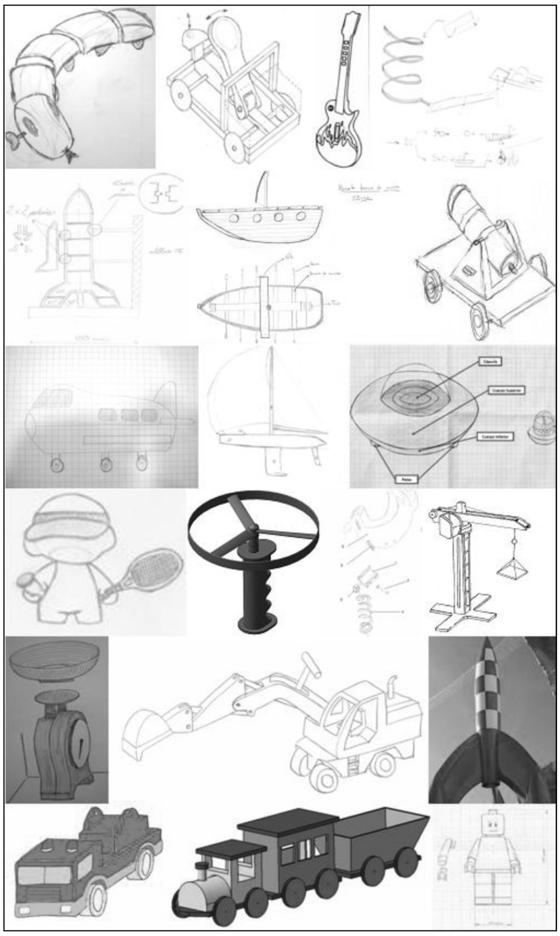

Fig. 2. Different examples of conceptual designs.

Fig. 3. Different examples of detailed designs.

subjects during their first years at Universidad Politécnica de Madrid. However 5 training sessions using the CAD Program 'Solid Edge' are placed at students' disposal at the beginning of the subject, so that every student has the opportunity to review the main concepts.

Moulding simulations are carried out in order to choose the optimum (theoretical) injection point or to evaluate times and temperatures obtained when filling the mould cavities. These are important studies for optimizing subsequent production processes. Additionally Fig. 4 shows different finite-element calculations in order to check both the parts design and the appropriate selection of materials, and Fig. 5 shows some injection moulding simulations for final material validations, as well as design check out.

3.4 Prototype manufacture

Using the CAD files provided by the working groups, and once the appropriate calculations have been made, the prototypes are produced by stereolithography technology as explained before (manufacture preparation is shown in Fig. 6). Using the rapid prototyping technologies available in the UPM's Product Development Laboratory (http://www.dim.etsii.upm.es/ldpdim/) brings students closer to these new technologies now becoming more widespread in industry, thereby giving added value to their training and allowing them to physically check the validity of their CAD designs.

Figure 7 shows some of the prototypes made for visual and assembly checks, paying special attention to tolerances, any possible interference and empty or useless spaces. Additionally Fig. 8 includes a schematic diagram of the development process followed, from initial drafts to final pre-production prototype, similar to the real product development process used in industrial real-life applications.

The prototypes also enable certain working trials to be performed, but the fragility of the epoxy resin materials of which they are made has to be taken into account. For tougher trials, a second prototyping stage can be carried out, involving the manufacture of silicone moulds for polyurethane vacuum casting.

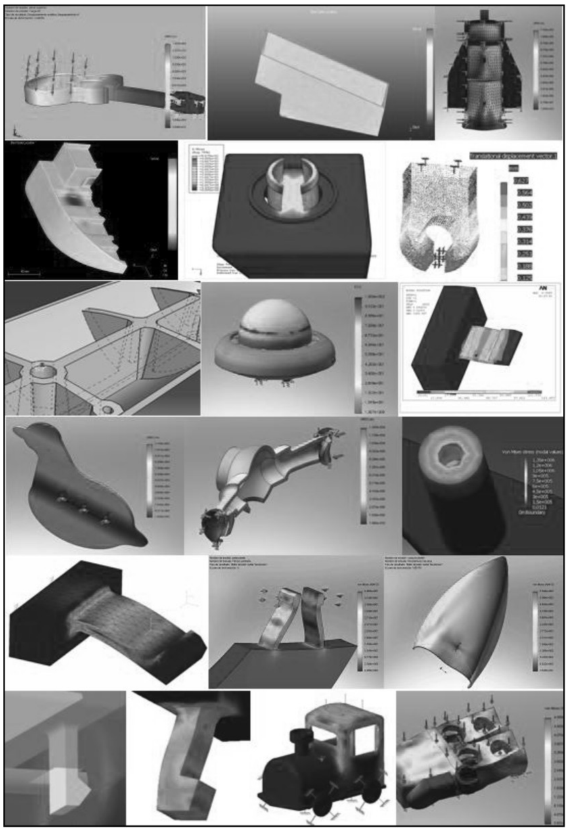

Fig. 4. Different F.E.M. simulations for design validation.

Fig. 5. Different injection moulding simulations for material selection and design validation.

During course 2008–2009 the costs for manufacturing the 10 prototypes of the selected best toy-designs laid around 2500 to 3000 euros. In previous years the costs for manufacturing all the prototypes laid between 1500 and 2000 euros, depending on the number of groups and size of the parts. The prototypes linked to the 'Toy Design Experience' were somehow more complex than those from previous years, what had influence on the manufacturing costs. For this purposes, we have been receiving some financial help of the following educational innovation initiatives:

- 'UPM initiative for the Creation of Educational Innovation Groups' (2007–08).
- 'INOVA.EDU 2006–07' initiative of the ETSII (Industrial Engineering UPM).
- 'INNOVA.EDU 2005–06' initiative of the ETSII.
- 'INNOVA.EDU 2004–05' initiative of the ETSII.
- 'The UPM Pilot Scheme for assisting educational innovation within the framework for implementing the European Higher Education Area and enhancing the quality of teaching'.

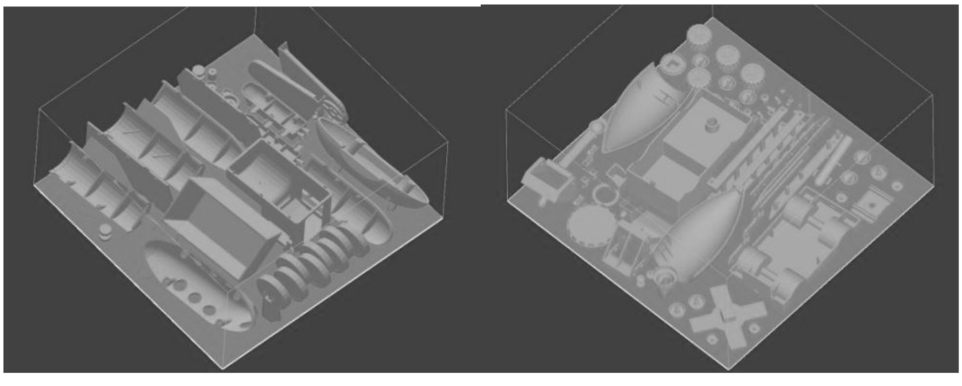

Fig. 6. Computer aided manufacturing: Preparation of stereolithography process for manufacturing student's parts.

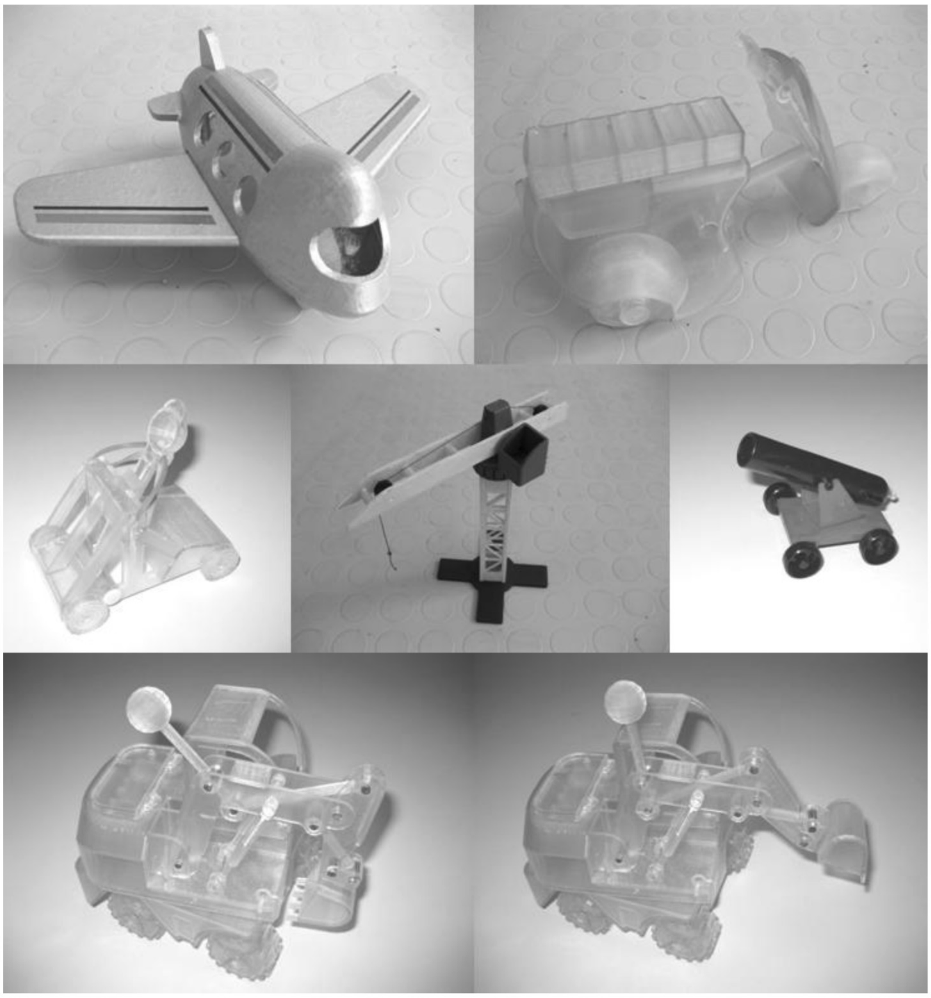

Fig. 7. Different examples of manufactured prototypes.

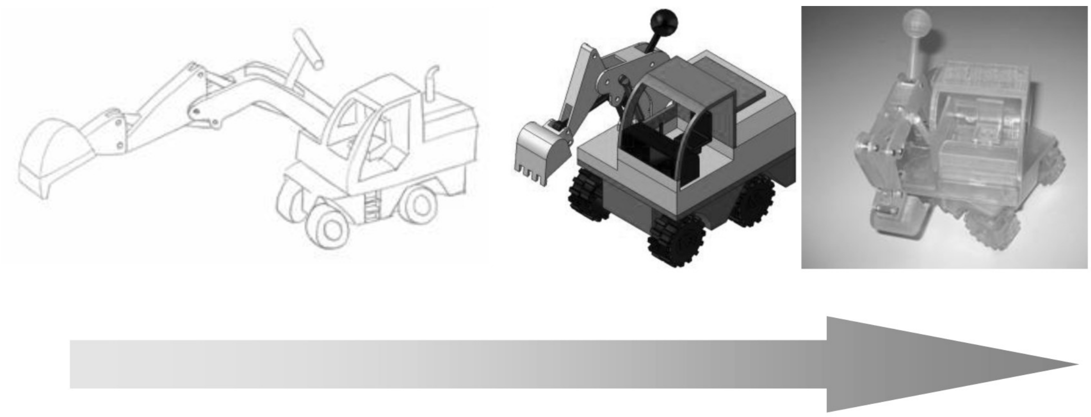

Fig. 8. Development process followed.

The UPM's Product Development Laboratory, whose main objectives are to provide prototyping solutions for industrial requirements and to assist teaching-learning activities at University, has helped at every moment with the costs not covered by the previously explained initiatives.

3.5 Verifying results and conclusions

Once the prototypes have been checked, the next stage is for the teams to make their final results public, and justify the decisions made in front of their teachers and fellow-students. The joint discussion on the different tasks performed means that

Table 1. Students' personal opinions

Students' opinion on different aspects	Mean score from 1 to 5
Knowledge acquired compared to other Mechanical Engineering subjects	3.81
Comprehension acquired related to the product development process	4.03
Knowledge acquired regarding polymer technique and design	3.98
Knowledge acquired regarding CAD—CAE—CAM tools	3.94
Knowledge acquired regarding RP&M technologies	3.60
Importance of teamwork activities within the subject	4.40
Students' workload	3.77
Possibility to apply the knowledge acquired in professional future	3.90
Coherence between explanations and assessment procedure	4.18
Overall impression of the subject	4.34
Toys as theme proposed for the products	4.42

each team learns from the work of their fellow-students thereby enhancing the teaching aims.

Such discussion is promoted by means of providing additional marks to those students showing the most productive criticisms and best proposals for designs improvements, when attending at the presentations of their fellow-students.

4. Main results of the experience

At the end of the course, a survey was made so as to assess the quality of the teaching experience, based on students' satisfaction and understanding about their own knowledge. The results are summarized below on Table 1 and explained further on. Each question was given values between 1 (for a very negative impression) to 5 (for a very positive impression).

The results show students' overall satisfaction within the subject and the very positive perception of their own acquired knowledge. We believe the theme proposed 'Toys' for the design team-works has enormously helped to promote students' motivation and final qualifications as shown in the assessment chapter.

Some future actions including visits to enterprises and technological centres, dedicated to product design and development, will help to increase their opinions on usefulness of the acquired knowledge for their future professional development Regarding the play-based methodology, 100% of students answered positively to the question 'Have you enjoyed your experience in the subject?' and 100% of the students answered positively to the question 'Do you believe enjoyment helps general motivation and improves final results?'

Among other personal opinions and some suggested improvements to the subject were:

> It would be interesting to make more complex machine prototypes or products by working together with different teams.
>
> Producing a second stage of prototypes would enable the solution to problems found in the first stage to be checked, and the design improvements proposed to be verified.
>
> The nicest thing about the subject is being able to see and touch your own designs.
>
> The workload required to develop the product is excessive.
>
> The number of theory classes should be reduced and the practical part of the subject increased.

Regarding the actual interest of using prototypes, a survey was carried out, after prototype assembly and trials, so as to ask students' personal opinion about rapid prototyping technologies and the importance of prototyping in order to validate the designs. The main results are set out below in Table 2.

An additional survey was made in order to quantify students' real dedication to the subject and validate the number of European Credits assigned to the subject (between 25 and 30 hours of personal student work per credit). The results are included in Table 3 at the beginning of the following page.

A total average of dedication of 84.8 hours/student was obtained, which is in line with the 3 European Credits assigned to the subject (between 25 and 30 hours per credit), and combines attendance at theory classes with individual work in accordance with the European Credit Transfer System (ECTS) guidelines. The balance between individual and teamwork is also noteworthy with 46% dedication to individual activities and 54% dedication to teamwork activities.

From these results it can be concluded that the scores given by students are positive, particularly the scores regarding knowledge acquisition and satisfaction in obtaining prototypes of the designs produced. However, there are still certain points

Table 2. Benefits of using prototypes

Evaluation of prototypes and RP&M technologies	Mean score from 1 to 5
Importance of prototypes as support tool	4.625
Quality of manufactured prototypes	3.875
Prototypes for detecting design errors	4.625
Prototypes as complement for CAD tools	4.5
Importance of redesign according to prototypes	4.5
Interest of the prototypes for teaching aims	5

Table 3. Students' workload

Dedication to the different work stages	Total average (hours per person)
Formal lessons (35 scheduled hours, non-compulsory attendance)	32.54
Attendance at tutorials	7.52
Product search and prior studies	2.23
Conceptual design	11.68
Detailed design	18.95
Prototype assembly and trials	6.44
Total	**79.36**
Dedication to editing and presenting papers	**Total average (hours per person)**
Preparing reports and presentations	4.24
Public exposition	1.5
Total	**5.74**
Work distribution (Individual/Group)	**Percentage (%)**
Percentage of INDIVIDUAL WORK	46
Percentage of TEAMWORK	54

that need improving in the general approach to the subject and in the participatory working methods.

Finally we would like to note that the number of hours dedicated by teachers to monitoring, listening to presentations and marking student projects is considerable. The number of hours dedicated to tutorials has also increased considerably with the introduction of application tasks, as questions had to be answered in a personal way, due to the great differences between the proposed toy designs. For future experiences we will consider the establishment of an active tutorial plan, including students that have already studied the subject and can help their younger companions, so as to provide students with a more personal teaching.

5. Actual benefits of the proposal

In order to assess actual benefits of the play-based methodology proposed, a comparison between final marks is included here. Students' personal scores on satisfaction within the subject and understanding about their own knowledge have already been analyzed. Now we focus on teacher's evaluation of students' actual knowledge regarding product design with plastic materials.

During 2007–2008 course a total of 57 students coursed the subject and during 2008–2009 course the total number increased to 71. In this way teacher's workload also increased but, for assessment purposes, we may consider both groups as comparable ones (both in size and previous knowledge regarding the subject). In both cases assessment was mainly based on results from team-work / designed product (up to 80%), with some influence on personal activities during formal lessons and attendance (up to 20%).

Additionally the difficulty of developed products is considered to be similar, as well as the criteria for marks assignment, for both courses. Among most valued factors are:

- Originality of the proposed product.
- Systematic design and development procedure.
- Systematic comparison of possible solutions.
- Application of the design concepts explained.
- Comparison between calculations and simulations.
- Assembly and trials of prototypes.
- Final functional result.
- Final esthetical result.
- Overall product difficulty.

The results from such comparison are included in Fig. 9 and subsequently explained. At the same time students' dedication to application tasks was analysed regarding to their final qualification, as shown in the regression plot in Fig. 10.

Results show that best scores were obtained by groups with the most hard-working students, so the proposal seems to be also very adequate to promote students' involvement and rewards based on personal work, as well as on overall product quality. Some strange results were also found, specially linked to groups declaring in the surveys huge workloads, although final quality of their products was not so remarkable. We believe some students might have completed the surveys with the belief that their answers might modify somehow final mark and therefore provided exaggerated scores.

From these results it can be noted that the proportion of very good developments increased from around 36% to around 61%. We believe such increase is completely linked to their additional motivation, and consequent workload devoted, due to

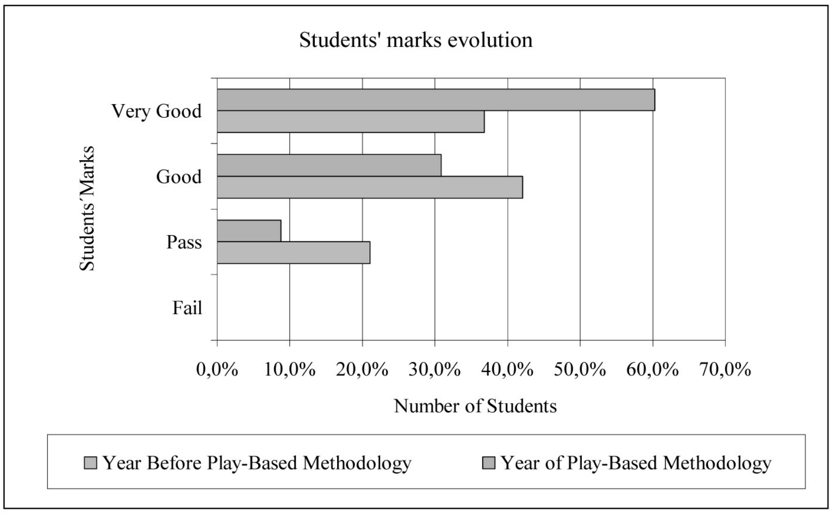

Fig. 9. Evolution of students' marks with the introduction of play-based methodology.

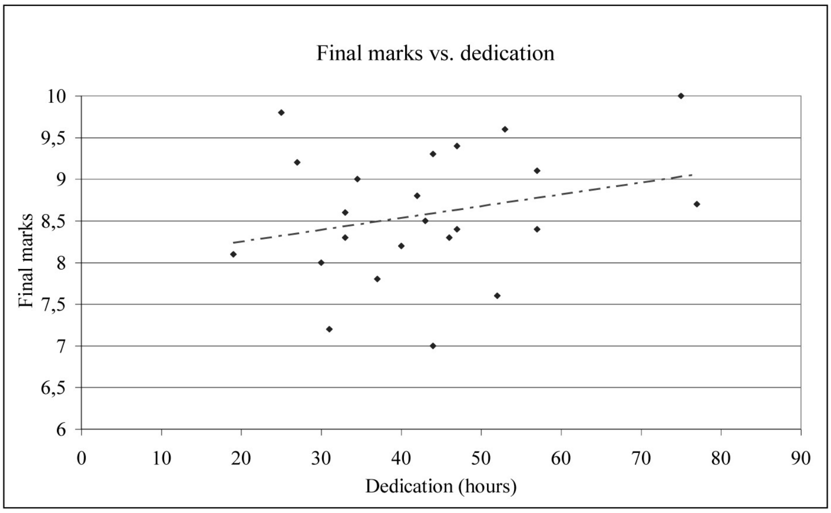

Fig. 10. Final marks vs. dedication to application tasks.

the proposal of a monographic on 'Toy design' (as also stated by students themselves in the satisfaction surveys gathered).

6. Conclusions

Learning through play has proven to be a great success, especially in areas such as primary education, foreign language courses and artistic education. In fact, several degrees on pedagogy include subjects for training future teachers in tasks linked to play preparation and its benefits for students.

However in recent years educational gaming has been progressively perceived as a very effective tool for improving teaching-learning activities in higher education. The use of such play-based methodologies for engineering education can promote several practical and communication skills of great value for students' future professional development, as our teaching-learning toy design experience has proved.

At the same time it is possible to increase students' motivation and to make them more aware of their own capabilities and the learning process. As a result there is an increasing interest among scholars in investigating this area, so as to quantify its actual effect on global learning and in order to apply its principles in a more efficient way.

Additionally, undertaking problem based learning and teamwork activities, where students can experience the complete development of a product or machine, following the stages used in the industrial world, brings them closer to future work experiences. Aspects such as active decision making, weighing up alternatives, self-teaching, time and cost planning, the application of regulations, design in line with commercial elements or contact with suppliers, are given an enormous boost.

Student learning, throughout projects such as these, benefits greatly from the use of computer aided design, manufacturing and engineering tools, (CAD-CAM-CAE tools) highly esteemed by companies dedicated to the development of machines and products. It has been shown that the use of rapid prototyping technologies enables students to come into contact with modern manufacturing technologies that are becoming widespread in Industry thereby giving added value to training. It is, in itself, a way of learning, since it lets designs be tested by performing assembly and working trials with physical parts.

The experience implemented for the subject 'Design and Manufacture with Plastic Materials' may be extended to numerous other subjects in Mechanical Engineering so as to obtaining integrated teaching in these subjects. The results have been highly satisfactory, both for students and teachers, all of which motivates us to continue with the experience and improve it in future courses. The correspondence between students' dedication and the European Credits assigned to the subject is very satisfactory, as can be seen from the surveys' results.

We believe students' attendance, motivation and results have been promoted through play-based methodologies, specially taking into account that the subject is part of the final year course, when many students prefer active learning activities and assessment through development works, rather than traditional lessons and final exam. We hope that the explained teaching methodology and assessment process can be of help for future researches on these areas.

Acknowledgements—Authors would like to thank students for their interest in the subject and for the quality of application works carried out. The images shown are results from their designs and prototypes, within the subject 'Design and Manufacture with Plastic Materials' during academic course 2008–2009. Such images have been included here also as a way for motivating future students.

References

1. Bologna Declaration of the European Ministers of Education, 1999.
2. L. Shuman, et al., The ABET 'Professional Skills' Can they be taught? Can they be assessed? *Journal of Engineering Education*, 2005.
3. D. Freitag and T. Wohlers, *Rapid Prototyping: State of the Art*, Manufacturing technology information analysis centre, 2003.
4. O. Weck, P. Wallace, P. Young and Yong Kim, *A Rewarding CAD / CAE / CAM Experience for Undergraduates*, Teaching and Education Enhancement Program. Engineering Design and Rapid Prototyping MIT, 2004.
5. R. Stamper and D. Decker, *Utilizing rapid prototyping to enhance undergraduate engineering education*, 30th ASEE/IEEE Frontiers in Education Conference, Kansas City, 2000.
6. J. Newcomer and N. Hoekstra, Using Rapid Prototyping to Enhance Manufacturing and Plastics Engineering Technology Education, *Journal of Engineering Technology*, Spring 2004.
7. O. Diegel, W. L. Xu and J. Potgieter, A Case Study of Rapid Prototype as Design in Educational Engineering Projects, *International Journal of Engineering Education*, **22**(1), 2006.
8. M. V. Candal and R. A. Morales, Design of plastic pieces and their moulds using CAD/CAE tools, *Computer Applications in Engineering Education*, **13**(4), 2005.
9. Díaz Lantada, P. Lafont Morgado, et al., Teaching Applications for Rapid Prototyping Technologies, *International Journal of Engineering Education*, **23**(2), 2007.
10. H. Lorenzo, A. Díaz Lantada, et al, Towards Complete CAD-CAM-CAE Product Development Teaching. *Computer Applications for Engineering Education* (Online 25 Feb. 2009).
11. G. Pahl and W. Beitz, *Engineering Design—A Systematic Approach*, Springer-Verlag (Second Edition), 1996.

Andrés Díaz Lantada teaches 'Design and Manufacturing with Plastics', 'Biomechanics' and 'Development of Medical Devices' at Universidad Politécnica de Madrid (Mechanical Engineering Department). His research interests are in the area of Mechanical Engineering including Product Development, Active Materials, especially for Medical Devices Development, as well as Educational Innovation.

Pilar Lafont Morgado teaches 'Machine Design', 'Design and Manufacturing with Polymers' and 'Machine Calculations' at Universidad Politécnica de Madrid (Mechanical Engineering Department). Her research interests are in the area of Mechanical Engineering including Gear Design, Tribology, Rapid Prototyping Technologies and 'MEMS'.

Javier Echavarri Otero teaches 'Machine Elements', 'Machine Maintenance' and 'Machine Calculations' at Universidad Politécnica de Madrid (Mechanical Engineering Department). His research interests are in the area of Mechanical Engineering including Tribology and contact phenomena, Security and Regulations for Machine Design.

José Luis Muñoz Sanz teaches 'Machine Elements', 'Machine Maintenance' and 'Machine Safety and Regulations' at Universidad Politécnica de Madrid (Mechanical Engineering Department). His main research interests are in the area of Mechanical Engineering including Security, Regulations and Standards for Machine Design.

Juan Manuel Munoz-Guijosa teaches 'Machine Design', 'Vibrations Theory' and 'Machine Development' at Universidad Politécnica de Madrid (Mechanical Engineering Department). He has worked five years as consultant, R&D engineer, and project and product manager in the automotive industry. His research interests are in the area of Mechanical Engineering including Mechanical Energy Storage, Rotor Dynamics, Practical applications of vibrations theory, Design Methodology, Process Reengineering, Educational Innovation and 'MEMS'.