

PRECISION ENGINEERING ACTIVE LEARNING SUPPORTED BY THE ICT

J.A. Yagüe-Fabra, J.A. Albajez, M.A. Lope, and J.J. Aguilar

University of Zaragoza, Zaragoza, Spain, jyague@unizar.es

Abstract: In this paper an effective continuous improvement methodology developed by a group of professors by using tools from the industrial quality field is proposed. Its application to a course on dimensional metrology and precision engineering in mechanical engineering is presented. The use of that methodology, active learning methods, such as project-based learning or hands-on learning, and new information and communication technologies (ICT) has allowed the development of a natural critical learning environment for the students of that course, improving their results, the skills they get and their satisfaction with their own learning. All these methodologies, their application and, finally, the results and conclusions from the evaluation of the implemented actions are presented in this paper.

Keywords: Precision Engineering, ICT, Internationalisation, Active Learning.

1. INTRODUCTION

The development of a “natural critical learning environment” is one of the main objectives that should be pursued in the design and development of subjects inside the new European university education frame. This environment allows the students to feel themselves much more implied and motivated with their learning [1]. In order to get that environment, traditional expositive lessons need to be complemented with other kinds of activities that allow the students to get a deep learning [2].

This idea is directly related to the new orientation of the teaching-learning process that the European Space for Higher Education (ESHE) [3] implies. In this new frame, Universities are responsible for the teaching and learning of up-to-date knowledge and skills as well as the development of the specific and generic skills that their students will need for their professional future. Therefore, this new framework does not imply only changes in the contents but also in the way they are learned. Thus, the traditional expositive system needs to be complemented with new active methodologies putting the student in the centre of the learning process and letting the professors be the coaches and promoters of their students’ work. Hence, it can be stated that we are living the change from the ‘University of Teaching’ to the ‘University of Learning’ [4]. In this new context professor role is not limited to transfer knowledge or contents but to design, coordinate and direct the learning process and activities. Moreover, this new role can be better played if the professor works inside a team of professors and not only on his/her

own. In addition, students must participate in an active and responsible way in their formative process.

In this context, the quality assurance of the learning process is of key importance. However, this is not something new and quality assurance and continuous improvement has been a concern in higher education since many years ago [5-7]. Therefore, continuous improvement philosophy is a powerful tool. In this paper an effective methodology developed by a group of professors by using tools from the industrial quality field is proposed and its application to a dimensional metrology and precision engineering course in mechanical engineering, as well as the analysis of the results obtained is presented. The use of that methodology, active learning methods and new Information and Communication Technologies (ICT) has allowed the development of a natural critical learning environment for the students of that course, improving their results and their satisfaction with their own learning. The methodology here presented is general and can be very easily extrapolated to any other course, not only from the mechanical engineering field, but from any other.

2. DESCRIPTION OF THE COURSE

The course where this methodology has been applied is called “Mechatronics and Precision Metrology” and it is part of a Mechanical Systems Master degree at the University of Zaragoza. In the course the students have to design a precision system by selecting the adequate components, proposing different alternatives, justifying and documenting them. The work is carried out in teams of two or three people and a number of deliverables have to be prepared by the students during the course. These intermediate deliverables are a powerful feedback and a useful formative evaluation tool.

The main goals of this course are oriented to the student to know and work with advanced measuring techniques in the manufacturing quality control as well as to select and integrate the adequate systems and equipments for precision equipment. The program of the course mainly deals about: basic concepts (errors, definitions, precision engineering design basic principles, etc), calibration and uncertainty calculation, coordinate measuring machines, sensors, actuators, kinematic couplings, flexures, mathematical modelling, etc. The course is taken by an average of ten students every year.

The professional skills to be obtained by the students were defined from the analysis of the academic and professional profile wanted for mechanical engineers in Spain. The main transversal or generic skills to be developed are listed in Table 1 and the main specific skills to be developed are listed in Table 2:

Table 1: Transversal skills to be developed by the students of the course

Main transversal skills
<ul style="list-style-type: none"> • Capability of organization and planning • Capability of analysis, synthesis and problems resolution • Capability of taking decisions • Oral and written communication • Autonomous learning and work • Work in group

Table 2: Specific skills to be developed by the students of the course

Main specific skills
<ul style="list-style-type: none"> • Capability of select and compare measuring techniques and equipment • Capability of handling technological variables from manufacturing engineering and quality engineering • Knowledge of the equipments and components to be able of deciding about the design and automation of a measuring process • Fluent knowledge and use of technical shop-floor and laboratory terminology.

3. CONTINUOUS IMPROVEMENT STRATEGY AND MAIN IMPROVEMENTS APPLIED

The group of professors responsible for the course decided to use a continuous improvement philosophy in order to obtain an improvement on the results with efficiency and efficacy. This methodology has a clear scheme Plan-Do-Check-Act (PDCA). A scheme of the steps followed is shown in Figure 1.



Figure 1: PDCA continuous improvement scheme

In order to establish the practical actions to be taken to get these objectives a Quality Function Deployment (QFD) was used. In the present research the inputs for the QFD (the “Whats”) were the skills to be developed by the students. On the other hand, the outputs (the “Hows”) were the concrete actions to be taken to get those objectives.

In previous semesters a traditional teaching technique based on expositive lessons and a final exam had been used. An analysis of the weaknesses and strengths found in the course in previous semesters was carried out. The sources of information used were the students’ (based on their opinions obtained from several methods), industrial companies’ and professors’ points of view always with the objective of meeting the goals proposed by the course by giving the best possible formation. The sources used for the analysis were diverse. The main were the following:

- Official surveys that students must fill out at the end of every semester.
- A simple survey run the last day of course were students were asked to write down the best thing and the worst thing of the course (this simple survey was a very interesting source of information for the main problems and positive points of the course).
- Opinions expressed by the students in informal conversations with professors.
- Ratios on students passing the course in the first chance every year, quality of the works presented, etc.
- Opinions of the companies where students from the course made internships related to metrology.

With that information the group of professors came up with a list of strengths and weaknesses. The most important weaknesses found were the following:

- Lack of connection between the different parts.
- Lack of complementary materials to carry out the final project.
- Lack of real feedback to and from the students.
- Lack of information to evaluate and improve the course itself.
- Students have difficulties to apply their theoretical knowledge.
- Too many expositive lessons.

To sum up, the main general conclusions obtained after using this methodology were: the program of the course was considered adequate and major changes would not be necessary; however, active methodologies should be introduced to provide the students with the desired skills; in addition, the evaluation methods should be improved to be in accordance with the new methodologies and to use them as learning tools themselves. Therefore, those are the processes needed to obtain the desired improvement objectives. In the next sections those processes, based mainly on active methodologies and ICT are explained.

4. LEARNING METHODOLOGY, TOOLS AND EVALUATION SYSTEM

The basic principle applied in the course is “learning by doing”. The “hands-on” philosophy is applied in order to use the practice as the main learning way. Students have free but supervised access to the metrology lab (Figure 2) where they make the measurements and experiments necessary to develop their course final project.



Figure 2: Manufacturing metrology lab and CMMs at the University of Zaragoza

However, physical presence in the lab is not needed for many of the tasks they need to carry out. That is one of the reasons why ICT were used as support for the active methodologies. Students can access to on-line catalogues and courses, communication tools, etc. through the web site of the course.

4.1. Learning methodology

Project-based learning (PBL) is applied: after some initial expositive lessons, a practical project is proposed to the students. The students have to design a precision engineering system giving different alternatives, reasoning them and documenting the decisions taken. This problem has to be solved in groups of two or three and it includes several deliverable intermediate works.

From specific design requirements given by the professors, students have to carry out the following tasks:

- Bibliography search: search for precision systems with similar requirements, both commercially available or at research level. Apart from the internet searchers, ISI Web of Knowledge, Science Direct, etc. are of big help in this step. RefWorks is one of the options suggested for managing the papers.
- Conceptual design: a first idea of the system structural and metrological frame, sort of components needed (actuators, sensors, etc), materials, etc. This design must be accomplish the main precision engineering principles.
- Selection of components in order to meet the equipment requirements. For each component at least two alternatives must be proposed (different principles for the sensors, different structures, etc). One of them must

be selected based on a reasoned analysis (uncertainty budget calculation, etc).

- Revised conceptual design: taking into account the specific components selected, their assembly, wire pass, etc.

The students have to present several deliverables with intermediate results during the semester. In Table 3 a summary of these deliverables for the spring semester is shown:

Table 3: Schedule for deliverables

<i>Deliverable</i>	<i>Date</i>
Report 1: Bibliography	April 7th
Report 2: Initial conceptual design and initial selection of components	April 14th
Report 3: Improved conceptual design and final selection of components	May 12th
Public presentation and discussion	May 19th
Final report	June 24th

Each professor coaches one or two groups of students during the project by meetings and by reviewing the intermediate deliverables that they have to present. Those deliverables and the following feedbacks provided by the professors to the students are a very useful tool for formative evaluation and learning improvement.

The project covers almost all the program contents of the course. This has shown to be very interesting in terms of the improvement in the attention the students pay to the expositive lessons, which are eventually very useful for their final project results.

The laboratory sessions are essential for the students to understand the precision engineering principles by a “hands-on” approach. During these sessions they must assemble simple precision engineering systems, which make them understand principles such as Abbe error, kinematic coupling design, etc. They must also measure with CMM simple or complicated parts as well as some of these systems. This presents the students the close tie existing between design and measurement. They also have to work with different sorts of sensors, etc. In such a way, they are able to understand the limitations and fields of application of these systems.

4.2. Evaluation system

Regarding the summative evaluation, the different specific and general skills are evaluated. Thereby, not only the deliverable work content is evaluated but also the deadline dates compliance, the quality of the final presentation to be carried out to the professors and the rest of the students (verbal and non-verbal language, structure, order, concepts transmission capability, etc.), the consequent

questions to be made by professors and students, etc. Thereby, the work in group is evaluated by several items:

- Laboratory work: 20% of the final mark
- Deliverables: 30% of the final mark.
- Final written report: 25% of the final mark.
- Public presentation of the results: 15% of the final mark.
- Continuous evaluation by the professors: 10% of the final mark.

The evaluation of the skills is carried out by means of rubrics with clear criteria that the group of professors have to fill out and put in common.

This evaluation method not only increases the practice as a learning method but also other methods that have proved to be excellent learning ways [8] like teaching to others (through the results presentation) and discussion (either inside the students work group or with the professor or the rest of students).

4.3. Other learning tools applied

Another information and communication technology used is the videoconference. This tool has been very useful to internationalise the course by collaborating with professors working in other Universities around the world. Last year this collaboration took place with a professor working at the DTU (Denmark). This professor gave a short lecture to the students about one of the topics of the course (sensors) and explained some of the applications of them to projects at DTU. A freeware videoconference tool allowing desktop sharing was used. After that, students questioned him about the topic but more focused on the design they have to carry out for their final project.

As part of the objective of internationalisation, professors from foreign Universities visited the University of Zaragoza and gave short seminars on Precision Engineering to our students. From 2008, four visits of professors from the DTU (Denmark) and the University of North Carolina at Charlotte (USA) have taken place. This activity opens the students' point of view about what they are learning and the importance of a global network of collaboration.

A key point in any experience involving people is the motivation. The last year, the professors of the course tried to increase the students' motivation by encouraging three of them to participate in an international competition: the euspen challenge [9]. This is an international competition organised by the European Society for Precision Engineering and Nanotechnology (euspen) to identify outstanding students across Europe within the field of precision engineering. Students benefit from national and international teamwork exposure, in addition to testing their engineering and business skills. They also gain experience in influential professional network building. In the 2011 edition, our three students became winners of the Spanish

competition and took part at the international competition in July 2011 in Cambridge, United Kingdom.

5. ANALYSIS OF THE EFFICACY OF THE TECHNIQUES USED

As part of the continuous improvement process the efficiency of the methodologies applied was checked. For this step control data have been gathered, analysed and compared to the initial objectives in order to find weaknesses, strengths and future improvement areas. For this goal, different tools have been used:

- Surveys to the students regarding the new way the course has been carried out.
- Suggestions expressed through the web site.

In addition, as a final part of the students' course project, they are asked to make a self-evaluation of their learning on the technical and personal level (regarding work in group, etc), difficulties found, etc. They are also asked to include which aspects of the project and the course should be improved from their point of view. This self-evaluation has two clear utilities: it is a very valuable source of information for continuous improvement and it is a very useful meta-learning tool for the students.

Regarding the general satisfaction with the course:

- General very high satisfaction (71%) with the course meeting the expectations the students had, although still 29% of them only agree and do not strongly agree with that statement. Therefore, some work will have to be done in this point.
- Even finding the course difficult (86%) or very difficult (14%), all of the students would recommend it.

Regarding the specific skills learning:

- The general impression of the students when they are asked whether they feel able to select and compare measuring techniques, express measuring results adequately, etc. is that they strongly agree in a 57% of the cases but only agree in a 43% of the cases. Therefore, although there are a considerable percentage of students not feeling completely sure with the skills they have gotten, all of them are satisfied with them.
- On the other hand, the opinion of the group of professors (based on the evaluation carried out and the monitoring of the students during the course) is that the students have developed all the specific skills planned. However, of course, not all of them have gotten the same level and the qualifications have been coherent with that.

Regarding the transversal or generic skills learning:

- From the self-evaluation and suggestions of the students and from the results of the evaluation carried out by the professors (with the help of adequate rubrics) it can be concluded that the course have really helped them to get

the main transversal skills planned. Capability of organization and planning, analysis, synthesis and problems resolution, work in team, etc. have been highly developed by the project, case-based learning and hands-on methodologies. The oral and written communication skill has been also very developed thanks to the reports, presentation and discussion of the project.

Regarding the active methodologies used:

- There is unanimity among the students in considering all the active methodologies very useful for their learning.
- In spite of having given a boost to active methodologies instead of expositive lessons, a 71% of the students strongly agree and a 29% agree with the statement "I feel I got a high theoretical knowledge". This feeling is corroborated by the results of their work. It seems clear that the inclusion of active methodologies does not go against the quality of the theoretical knowledge obtained by the students in the course.
- Regarding expositive lessons, 43% of the students find them very useful and 57% find them only useful. This percentages contrast with the 100% that found very useful the project or the 86% that found very useful the laboratory sessions, etc. Therefore, expositive lessons could be reduced even more and practical sessions augmented.

Other general conclusions obtained from the application of active methodologies are that the project covering almost all the program contents of the course has shown to be very interesting in terms of the improvement in the attention the students pay to the expositive lessons and laboratory sessions. In addition, the real and immediate practical applicability is one of the pros of the project, highlighted even more by the collaborations of external professional. This characteristic of applicability is also evident in the practical measurements (hands-on) that the students have to carry out. Moreover, that environment and the students' implication in their learning are not limited to the activities carried out in class or in laboratories, but also in any other place thanks to the ICT, increasing their learning motivation

Summing up, it can be stated that the objectives have been highly obtained, but some still improvements have to be carried out.

6. CONCLUSIONS AND FUTURE WORK

A new methodology based on quality engineering methods and a continuous improvement cycle has been presented in this paper. The Plan-Do-Check-Act cycle has been applied to a course on precision engineering, although this general methodology could be applied to any kind of course. The steps carried out and the main conclusions obtained from their application have also been shown.

As a part of the continuous improvement actions, learning methods and evaluation tools, proved to be very efficient for an active learning, have been applied: the

project-based learning, the case-based learning, the hands-on learning, the formative evaluation, etc. Apart from that, all these methods have been complemented with the use of the Information and Communication Technologies (ICT) to assist in the creation of that "natural critical learning environment" and towards the internationalisation. Hence, that environment and the students' implication in their own learning are not limited to the activities carried out in class or in laboratories, but also in any other place, increasing their learning motivation. All these methodologies assist the students to develop their specific and general skills, which are inferred and designed together with the objectives of the subjects. Finally, the results of the evaluation of the methodology offer also very valuable information for future work in reinforcing the strengths and correct the weaknesses of the course.

Apart from the continuous improvements in the course, future work has to be carried out monitoring the results of this initiative for several years to observe tendencies and the long term effectiveness of the continuous improvement cycle. The opinion of companies where students end up working will be also very useful for that analysis. Finally, a future challenge of this work will be its application to other kind of courses and to groups with a higher number of students.

7. ACKNOWLEDGMENTS

This work was sponsored by the University of Zaragoza Teaching Innovation Project PESUZ-11-7-221.

8. REFERENCES

- [1] K. Bain, What the best college teachers do, The President and the Fellows of Harvard College, Cambridge (2004).
- [2] M. J. Prince and R. M. Felder, Inductive teaching and learning methods: definitions, comparisons, and research bases, *Journal of Engineering Education* 95, 123-138 (2006).
- [3] CRE: Confederation of EU Rectors' Conferences and the Association of European Universities, The Bologna declaration on the European space for higher education: an explanation (1999).
- [4] J. Bowden and Marton F, The University of Learning, London: Routledge Falmer (1998).
- [5] N. L. Hansen, Bringing total quality improvement into the college classroom, *Higher Education* 25, 259-279 (1993).
- [6] B. B. Burkhalter, The evolution of a continuous quality improvement process in a university setting: a working model for consideration, *Total Quality Management* 5, 169-184 (1994).
- [7] S. P. Mukherjee, Quality assurance in an education system, *Total Quality Management* 6, 571-578 (1995).
- [8] H. Lang and A. McBeath, Fundamental principles and practices of teaching: a practical theory-based approach to planning and instruction, Faculty of Education, University of Regina (1992).
- [9] <http://www.studentchallenge2011.euspen.eu/>