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An innovative approach toward first-year mechanical engineering students' conceptual difficulties in engineering design

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ABSTRACT: This article represents an account of the experience during the past three years of teaching a first-year mechanical engineering design course. The students are taught using advanced Information and Communication Technology (ICT) tools and working in teams, they must produce solutions to small engineering design problems. The learning outcomes of this approach differed between professors. The *traditional* professors found that the students did not obtain the substance of engineering design due to use of the sophisticated software, while the new generation of professors found the experiment a challenging one. The students much appreciated the new teaching methodology even though the learning outcomes were extremely demanding. The proposed learning environment provides the technological framework and experiences they will meet in their future working environment. The author's aim is to identify the *pros* and *cons* of using modern ICT tools (a combination of traditional/CAD instruction, videos and e-learning) in connection with problem-solving projects to deal with object visualisation problems in a first-year technical drawing course.

INTRODUCTION

A fundamental skill required of mechanical engineers is to visualise parts and to interpret the views of an object represented in design. The majority of first year students have serious difficulties in understanding engineering design. The intention has been to design a learning environment based on Information and Communication Technology (ICT) in combination with a project-centred teaching approach to tackle the above problem. The main targets of this approach are:

1. To facilitate the learning procedure and improve learning outcomes.
2. To develop reflection and visualisation abilities and special imaging.
3. For students to become accustomed to the computer work station as his or her learning environment by the end of the first year of studies.
4. To establish a spirit of collaboration among students and for them to learn how to criticise and evaluate their own and others' solutions.

One of the basic competences of an engineer is solving engineering design problems [1]. Therefore, engineering students have to be trained in developing spatially related problem-solving abilities. Technical drawings have been used to communicate ideas from ancient times to the modern era. As the vernacular of industry, technical design, drafting and drawing are essential to the curricula of all technology engineering and design programmes. Using lines and symbols to represent the thoughts and ideas of engineers provides a more effective means of communicating these concepts than do verbal descriptions.

The need to learn how to read and write a drawing is absolute, because all people related to technical industry must be capable of reading or interpreting a drawing without hesitation [2]. The technical drawing is an entry-level course and a prerequisite for advance design courses. A primary goal in technical drawing courses is to help students develop the knowledge and skills needed to function as mechanical engineers. The most difficult skill that students of a mechanical engineering department must acquire is to study the views of an object and to form a mental image of it, meaning to visualise its three-dimensional shape [3]. Expressed another way, visualisation is a mental comprehension of virtual information.

Spatial visualisation ability has been recognised as a predictor of success in many technology-related fields [4]. The transfer of three-dimensional objects to images on two-dimensional surfaces by means of geometric drawings has evolved from the crude drawings of prehistoric man to the well-developed drawings of today [5]. For engineering students, visualisation skills can be very important for understanding fundamental concepts of technical drawing [6]. Many students have difficulty in understanding or comprehending the graphic representation of three-dimensional objects: *One major limitation of traditional instruction is the problem of presenting three-dimensional spatial information (3-D) in a two-dimensional format (2-D)* [7].

The difficulty in understanding and learning the technical drawing is proven by the failure rate in our department, which is about 20%. Similar or greater failure rates have been reported by other researchers [8]. According to Perez Carrion and Serrano, the main reason is difficulty in understanding the mechanisms, which are related to the representation of three-dimensional objects on the paper of two-dimensional forms [9]. It was also found that the Technological Educational Institute students, who had studied drawing in secondary school, have not developed their spatial ability sufficiently. This failure ties in with results from other international studies [10][11]. The empirical research, carried out here, showed two reasons for high rates of failure:

1. The traditional teaching methodology that was implemented years ago.
2. The missing connection between the drawing and the design of the product itself.

TEACHING TECHNICAL DRAWING USING ADVANCED ICT TECHNOLOGY

One major concern of university teachers in the context described above ought to be integration of sophisticated ICT into the teaching and learning process. For many years, the Institute has experimented with more effective ways of teaching, to improve the learning outcomes of technical drawing concepts based on traditional approaches (still image transparencies, chalkboards with large manual drawing instruments and physical mock-ups, small projects, etc). The results of these efforts were marginal, as Nwoke proved that the problem is not necessarily the students' inability to *visualise* spatial relationships but rather the instructional methods used to present the information [12].

The explosion of ICTs has presented the academic society with an opportunity to support and nurture students' creativity and deep learning. The challenge is to match learning outcomes with appropriate ICTs [13]. At the early stages of the experiment - three years ago - the presentation of course lectures using PowerPoint software was implemented. It was noticed that this had no influence on students' understanding of the basic principles of the drawing and improving their achievements in the course. Students considered the use of ICT only during the classroom/lab sessions [14]. The only positive aspect was related to the availability to the students of the training material at any time. None of the problems noticed by many researchers regarding visualisation was addressed.

Research suggests that combining traditional drafting and Computer-Aided Design (CAD) instruction makes sense. Later on, AutoCAD Mechanical was used to present technical drawing. AutoCAD Mechanical, the 2D drawing package, provides hidden line removal, isometric views and other 3D functions. Its benefit is that it introduces the AutoCAD user to 2D mechanical structure, which allows he or she to work with associative features, parts and assemblies instead of lines, arcs and circles. This enables users to organise, store and reuse its structure-based designs more effectively in collaborative environments [15]. Information technologies can change the quality of the learning experience and environment for assessment [16].

The ICT methodology in teaching the mechanical engineering design course has been used since 2002 and results of this approach have been very encouraging. Students first learn and practise all concepts using traditional drafting equipment, then use CAD for the remaining two-thirds of the course. Students produce accurate drawings at an accelerated pace when using CAD software. At the conclusion of the combination of traditional/CAD instruction, it is always amazing to see the significant increase in the number of drawings produced and concepts learned, compared with teaching traditional drafting methods only. The literature provides a substantial amount of research supporting the effectiveness of early Computer-Assisted Instruction (CAI) systems when used properly [17].

The most positive feature of multimedia-based instruction has to do with capturing and maintaining students' attention as they see things happen. As a result, the videos used within the context of technical drawing instruction improved learners' attention provided they were available to them at all times. If the multimedia software is available to students at any time, it gives them the freedom to repeat the learning process at a convenient time and pace. It respects the specific learning abilities of the students much more than does traditional instruction and provides flexibility, accessibility and convenience *just in time and just enough*.

Brown pointed out that instructors, who desire the learning process to be more student-centred, must become aware of the different kinds of learning experience [18]. As the learning curve of the drawing concepts and skills improved, it was decided to introduce the design of a specific product based on small teams' work at the end of the first year of studies. In that way, the intention was to improve the understanding of drawing as a fundamental tool to solve specific problems. The main task of this approach was to give a holistic engineering education in order to cover the majority of learning attitudes.

A PROJECT-CENTRED TEACHING MODEL

Motivating students is certainly a stimulating and challenging task that is always present in teaching activities. Many factors are involved, such as non-stimulating subjects, knowledge transmitted essentially by oral expositions, student motivation, the teacher-student relationship, student and teacher social problems, and others. Certainly, there can be other problems related to the teaching methodologies. Teaching engineering design is a much-demanded subject and the majority of the teachers consider it *a classical subject* that follows very traditional teaching methodologies.

The use of ICT in teaching engineering design has promoted an enriched methodology with promising learning outcomes. The project-centred teaching model gives opportunities to captivate students for knowledge acquisition and to cultivate team spirit. As stated in research reports from the British Educational Communications and Technology Agency (BECTA), teamwork is emphasised as a decisive factor for effective use of ICT. The introduction of small-scale projects intended to help students meet the following objectives:

- Minimise the gap between what is normally taught at academia and what the new professional encounters in the real working environment.
- Promote individual capacities for the analysis and critical interpretation of case studies.
- Develop scientific thinking and technical competencies to resolve engineering and industrial design problems.
- Develop innovative and creative attitudes.
- Develop and stimulate co-operative and responsible attitudes.

The design project makes the students run through a (simplified) design process of six phases: problem analysis; product design specifications; concept solutions; evaluation of the concept solutions and selection of the best concept; detail design; and preparation for manufacture [19]. Even though the course is taught to the first year students, it was found that case studies and small-scale projects offer a new spirit in teaching engineering design. Students were excited to contribute with very innovative solutions. The key point is that any solution given to a particular problem is correct, if the design follows the theory that has been taught. In this way, creative thinking through originality was encouraged. Another important competency of an engineer is the ability to work in a team. The teams consisted of between five and seven students and were formed randomly. Each team was given a simple engineering design problem that took into account the limited technological background of the students, provided the stage of their study. Students were trained how to run team meetings in order to achieve their goals. At the end of the year, each team was obliged to present their project.

THE TUTOR

The latest approach in teaching of using the personal project instead of team project caused inconvenient situations for the tutors. The meetings and the progress of each team are monitored by a tutor and guided by the manual during the whole semester. Tutors are obliged to watch carefully the progress of the team and, at the same time, the parameters chosen by the individuals. Each tutor is responsible for one of the projects and has to monitor the teams working on the project at the same time but independent of each other. It is the task of the tutor to answer questions on the design problem, to play the role of customer during the first phases of the design process, to keep an eye upon the time schedule, to evaluate the students and to give feedback. The above approach has changed dramatically the quality of teaching of drawing-design and some part-time tutors decided to quit their posts.

The curricula of mechanical engineering and industrial design courses must be devoted to the acquisition of know-how and competencies for easy integration of the new professional (ex-student) into the working environment, minimising social and physiologic impacts that the transition often provokes. The results of this study indicate that multimedia computer-based instruction, in combination with specific problem-solving, holds promise for improving engineering design teaching.

The range of multimedia-based instructional development is quite broad, varying from relatively simple productions consisting of text combined with clip art or other digitised images, to interactive and dynamic presentations. The development of teaching material using video techniques requires that instructors have high quality equipment and abilities. As the majority of colleagues do not have relevant abilities, universities and institutions must provide suitable support. Also, classrooms must be equipped with proper projection systems, high speed Internet connections and effective communication systems between the instructor and students.

The sophisticated techniques involved in a multimedia presentation (combination of hypertext, graphics, animations, audio and video sequences, etc) are powerful tools for developing a new generation of teaching and learning programmes, as are interactive communication networks. For engineering design subjects, the main task when using these techniques is the adequate preparation of content. The other prerequisite is the selection and preparation of the learning content. For this target, a tried and tested method is to divide the subject into teaching modules.

The second part of the teaching approach - the team project - is associated with helping students to develop a robust understanding of technical drawing. It also enables students to make connections between the theoretical design principles, build complexity and apply their learning to real life problems. Collaboration in groups is a central way of learning in modern communities. The project-centred methodology helps students' understanding or refines their critical thinking skills and understanding of the others' viewpoints. Similar experience in other institutions confirms the benefit of integrating design projects in engineering education [20][21]. The experiences accumulated during the last three years show that it is worthwhile to instruct first-year students to do small exercises on the design process. The students considered it an enrichment of their engineering studies to learn - right from the beginning - about a complete design process.

CONCLUSIONS

The learning environment that was created gave students the opportunity to understand fully the working environment they will face as graduates. In contrast to the idea of learners as *passive recipients of knowledge*, the interactive environment encourages students to participate in the learning process. Sharing ideas and engaging in team discussions are forms of self-reflection. Team discussions also provide opportunities to reveal areas of misunderstanding, and to communicate as an engineer, based on the common language of the engineering community.

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