REFORMULATING THE WAY WE TEACH ENGINEERING: A NEW METHODOLOGICAL PROPOSAL

Jomar Barros Filho
Universidade São Marcos
Rod. José Lozano de Araújo, s/n
Parque Brasil 500 – Paulínia
São Paulo – Brasil – 13140-000
jomarbarrosf@bol.com.br

Fernanda Oliveira Simon
Faculty of Education – Unicamp
Rua Bertrand Russell, 801
Cidade Universitária – Campinas
São Paulo – Brasil – 13083-970
fersimon@uol.com.br

Dirceu da Silva
Faculty of Education – Unicamp
Rua Bertrand Russell, 801
Cidade Universitária – Campinas
São Paulo – Brasil – 13083-970
dirceu@unicamp.br

Estéfano Vizconde Veraszto
Faculty of Education – Unicamp
Rua Bertrand Russell, 801
Cidade Universitária – Campinas
São Paulo – Brasil – 13083-970
estefanovv@terra.com.br

Alan César Ikuo Yamamoto
Faculty of Education – Unicamp
Rua Bertrand Russell, 801
Cidade Universitária – Campinas
São Paulo – Brasil – 13083-970
alancesar@terra.com.br

Nonato Assis de Miranda
Faculty of Education – Unicamp
Rua Bertrand Russell, 801
Cidade Universitária – Campinas
São Paulo – Brasil – 13083-970
mirandanonato@uol.com.br

Alexander Montero Cunha
Faculty of Education – Unicamp
Rua Bertrand Russell, 801
Cidade Universitária – Campinas
São Paulo – Brasil – 13083-970
amcunha77@hotmail.com

Abstract. *One of the problems that surface today when analyzing the much-needed changes in the engineering courses is the fact that most professors-engineers are unprepared to form the modern engineer. Because such teachers were trained in a traditional way, in which the priority was technical knowledge and, due to the fact they lack the pedagogical knowledge and support, these teachers merely reproduce this way of teaching. Similarly, the engineering teaching program has not been preparing the students for the work market. They lack basic abilities such as, problem solving, teamwork and project management skills, for example. Thus, there is a need for a new background, that is, a restructuring of the courses in order to respond to the new expectations of the work market, since little real change has taken place in the engineering graduation courses, in relation to teaching methodology. The objective of the present paper is to make a critical analysis of the teaching-learning process in engineering, pointing out several problems, besides the main difficulties faced by teacher-engineers to achieve effective changes in classroom methodology. Based on that we will devise an example for changes in the methodology, which can really be implemented. With such changes, we hope to form an engineer who is more critical and able to face new challenges.*

Keywords*: teaching methodology, teaching engineering*

1. Introduction

A lot has been discussed and proposed about the much-needed reform of engineering courses. Many papers have pointed out the need for change in the curriculum, inclusion of new subjects, and to provide a more humanistic background for engineers. (Rompelman, 2000; Raju e Sankar, 1999). However, despite all the discussions and proposals, the graduation courses have undergone little effective and concrete change (Bazzo, 1998).

So, besides declaring the need for reform, we also know what we want to achieve: form an engineer who is better prepared to respond to the new market demands. However, it is clear that the graduates still lack the knowledge and abilities, which are fundamental for the practice of their profession (Raju e Sankar, 1999).

A more profound analysis of this scenario reveals that the majority of the teacher-engineers are unprepared to educate this modern engineer. This happens because such teachers were taught in a traditional way, in which priority was given to technical knowledge and, due to a lack of pedagogical knowledge and support, these teachers merely reproduce this way of teaching, which was able to meet the requirements of the market decades ago.

A great part of the teaching process is centered in lectures in which the students hear the teacher giving instructions for solving an exercise. The majority of the teachers in graduation courses in engineering still insists on a teaching methodology, which prioritizes memorization of ready-made concepts, which does not allow the student to develop critical reasoning and creativity, forming engineers with a vision that is detached from reality (Leitão, 2001; Wellington e Thomas, 1998). Students are, in general, asked to solve only standardized and well-defined problems, in the sense that there is only one possible correct answer, which is the one expected by the teacher (Barros Filho *et al*, 1999). Few teachers are concerned with approximating the reality of the work market and the classroom (Zainaghi *et al*, 2001).

This kind of education would be interesting if the students were to work in industrial-military complexes after the World War II. However, at the present, the engineer is asked to make decisions quickly, many times without having access to all the elements of the problem. With the ever-growing technological advances and great quantities of information being generated each moment, it is very unlikely that one isolated person will have all the knowledge necessary for the solution of a complex problem, thus teamwork is indispensable. Besides, as the time lag for great technological changes is of the same magnitude of an engineering course, a constant update of the teacher, in his/her area of teaching expertise, is necessary.

This paper will present a critical discussion of the teaching-learning process in engineering, pointing out several problems, and the main difficulties faced by teacher-engineers in order to implement effective changes in their classroom methodology.

2. The Issue of Teacher Background

Engineers, who have no pedagogical background, form the majority of the Teachers' Body of engineering schools. A great number of them have high levels of specialization and titles, profound knowledge of the specific engineering subjects (Lopes, 2002; Leitão, 2001). However, when it comes down to actually teach such contents, teachers stumble across many difficulties, as they do not have, and it has never been a requirement that they did, pedagogical background. (Ferreira, 2002; Lauria *et al,* 2001).

Some know extensively the subject, but simple do not know how to teach it. Others, in the absence of a pedagogical method, reproduce the traditional teaching process in which the student just sits there and listens to the explanations of the teacher about the concepts he/she should learn. In lab sections, the methodology does not differ much. In those classes, the teacher asks students to work under a certain number of pre-established procedures. That is, for the conduction of the experiments there is a "recipe" which must be strictly followed: assemble device XX, mesure parameters YY and using pre-determined equations arrive a conclusion ZZ. As engineering students deal solely with close problems, they are not required to make a qualitative analysis of the problem, or even to propose and test their hypothesis (Sánchez *et al*, 2002).

This was the way through which most of the teachers were taught. Many think: "if it worked for me, why wouldn't it work for my student?" However, they forget that times have changed. Traditional education, focused on the acquisition of technical knowledge, used to form good engineers up to the 50s (Bazzo, 1998). At that time, engineering schools would be successful if the student acquired knowledge and abilities to start the career. This meant that they had to be well prepared in science, once they worked in industrial-military complexes or aerospace systems, whose focus was placed on technical skill (Bucciarelli *apud* Rompelman, 2000). Besides, it was common for an engineer to begin and finish his career at the same company. Thus, engineers worked in an uncompetitive market, with technology that remained in use for long periods of time (Salum, 1999).

Moreover, there is a "low self-esteem", in relation to teaching, among many university teachers. Many are "incidental" teachers, in the sense that the choice of this profession was based in the quest for a career in research and not in education. That is why; such teachers make decisions during classes guided solely by intuition and previous experience as students (Ferreyra e González, 2000; Jiménez e Segarra, 2001).

That is the reason why many teachers do not realize the necessity for a change in methodology, and dwell on the misconception that traditional education fulfills the needs of the market. In this context, the teacher does not reflect upon his/her classroom practice.

3. Articulation among subjects

Traditionally, graduation courses in engineering exhibit the following structure: " basic and professional subjects". The former are related to basic sciences (mainly physics and mathematics), and the latter are formed by a set of subjects that are specific for each major in engineering. Elective subjects of a more general character complete this nucleus (Maines, 2001). All these subjects are viewed separately, without any relation, as if they belonged to different universes.

On the other hand, even within each of these structures, the subjects are not related. The teaching activities are compartmented, without a coherent vision of the whole. In this context, the main characteristic of university educational practice has been to offer a greater volume of information to students (Ferreyra e González, 2000).

4. The need for new abilities and competencies

Furthermore, for some time now, the objectives of teaching engineering have stopped prioritizing only the acquisition of formal knowledge, translated into the contents of several of the subjects, which comprise its curriculum, and started emphasizing the need to develop several abilities and competencies (Rompelman, 2000; McNally *apud* Huxham e Land, 2000), considered to be growingly important.

Nonetheless, a first glance at the structure of a great part of the graduation courses in engineering and, consequently, of the pedagogical practices occurring in the classroom, suggests that such abilities e competencies are not being fully developed by future engineers. At the same time that the university, in most of its graduation courses, presents information without considering the social context in which they are inserted, it also does not allow students to develop their own methods for solving problems that are closer to reality. (Barros Filho *et al*, 1999).

Thus, many graduates lack the knowledge and abilities, which are of chief importance to the practice of the profession (Raju e Sankar, 1999).

One possible cause for this lacuna can be attributed; in part to the way the subjects of graduation courses in engineering are structured. The subjects are compartmented, that is, they are taught in distinct blocks, very often without any relation to the others. As the integration among subjects is left to the students, it usually does not occur. In relation to this issue the Curricular Guidelines for Engineering (Brasil, 1999) state:

(...) *It is emphasized that the items below do not necessarily correspond to individual subjects. It is recommended that they be distributed along academic activities (...) Administration, (...) Economics,(...) Environmental Sciences,(...) Humanities, Social Sciences and Citizenship (...). (Brasil, 1999).*

Even though the document cited above gives indications that this theme has began to be discussed in the academic fora, this is still the very beginning and the compartmentalization of the contents of subjects is a reality which is difficult to change. This can be seen when new subjects, such as entrepreneurism and ethics are created, instead incorporating those themes in the existing subjects.

The way each subject is pedagogically organized also seems to contribute for its isolation. Teaching is often based in the transmission/reception of previously elaborated knowledge. In this sense, according to Nieda and Macedo (1997), this model conceives science as a complete corpus of knowledge, which is formed by juxtaposition. In the beginning of education, students are viewed as having an empty mind. Each class, the teacher transmits (in general, through an oral explanation with the aid of the board) a little knowledge to the students. In this model, it is assumed that students learn by watching teachers' lectures, and repeating by coping and solving standardized problems.

This way, students have passive attitudes towards knowledge, which do not allow problems derived from reality to be tackled or new abilities developed. As passive receptacles of information, the most they can do is learn how to reproduce what already exists. There is no possibility of working with open-ended problem-situations, in a more investigative and creative manner, conducting qualitative analyses, proposing and testing hypothesis, working cooperatively in groups, testing the limitations of the models in use, and deciding which theories should be used, etc.

5. New Classroom Methodologies

No one disagrees that a good teacher should know the contents of the subject being taught. However, knowing about the contents of the subject is much more than simply knowing how to solve exercises proposed at the end of each chapter of the textbook. To know what must be taught means: a) know about problems and the context in which scientific knowledge has developed, specially, the epistemological obstacles that have hindered its progress; b) know the methodological strategies employed in scientific constructs; c) know about the interplay between Science and Technology and its relation to society associated with scientific knowledge; d) have some knowledge about recent scientific development and its perspectives in order to acquire a view of Technology that is dynamic and in permanent evolution; e) know how to select content which is adequate and that give a correct view of Technology, at the same time accessible and interesting to students (Gil Pérez, 1991; Furió, 1994).

Besides this broader vision of what it is to master the contents of a subject, a background in pedagogy is also necessary, so that the teacher can propose learning activities, which instigate and appeal to students, and in doing so establish new methodologies in the classroom.

Even when the teacher is concerned with proposing new learning activities, their actual implementation is complicated. First, because what "works" with one class, might not with the next. Secondly, because the activities must be modified for each class, mainly in new terms, since the new students will have "hints" about the subject, which are supplied by the previous students.

Another aspect that must be taken into consideration is the attitude of the teacher toward new methodologies. To simply tell a teacher that his classroom practice must be changed is not enough for change to be made. The teacher needs to "buy into" the idea. That is, he or she must be unsatisfied with students' results and feel an urge for change. Moreover, when management or the government makes proposals, in general, they do not supply the resources or support to the teacher for implementation of change.

On the other hand, their own colleagues criticize many teachers because they are concerned with issues related to education. When they publish papers in symposiums and congresses or periodicals, they are viewed as not competent to work in the technological field (Bazzo *et al*, 2000).

6. An Example of a Teaching Approach in Engineering for Experimental Subjects

First, if we intend to devise a new methodology for teaching experimental subjects, we must abandon the idea that to have laboratories suffices. The teaching of experimental subjects cannot be viewed as self-sufficient, as an absolute situation, whose mere existence the condition to teach and form critical engineers.

We must also overcome the idea that seeing is learning. A more sensible teachers knows that in more traditional teaching situations, lab activities become boring, and require more "muscle" than significant learning.

Furthermore, the equipment and devices must be prone to "control-loss", that is, they must contain variable elements, which allow them to be tuned at will.

This way, we seek to create an investigative environment in which the experiments are initiated by questioning that allows students to think about what is being taught, about the phenomena involved and about alternative ways of performing the same experiment. In a conception, which is closer to reality, we must allow students to have access to information about what kind of Technology is involved in the devices and about the elements of their development history.

Nowadays, differently from a recent past, new Technology is not developed in an isolated manner. There is a need to work in teams, and the engineer must be able to venture in this context and allow everyone to grow. Thus, it is necessary to foster teamwork. The issues proposed above must be discussed and debated by the team and a set of proposals and solutions must be presented for discussion by the whole class. Only after that we suggest beginning the experiments.

So, in this context it is important to create a metacognitive perspective. One in which the students may reflect upon what has been proposed and what they see in practice, as a means of preserving the debate. The students must be inspired to cultivate a critical and investigative spirit, in relation to themselves and others.

After that, a report must be written with a set of systematizations of the process, in which the process experimented is more important than the results (bureaucratic) that the group may present. The systematization and reflection upon the processes allows students to develop their own solution-searching methods. When we educate students, which may consider paths different from the ones already traveled, we create habits of autonomy and development of new possibilities. The construction of new possibilities distinguishes the level of the professionals and the quality of the possible adaptations they will introduce in their work environment.

To do so, during the whole process, we must allow students to formulate and test hypotheses. In many universities there are well structured workshops, which could, among other things, help students construct new equipment, make structural changes in the existing ones or combine new elements onto them. This way, the labs become much more conceptually dynamic, besides establishing an invaluable bridge between academic theoretical knowledge and the knowledge and experience of technicians working on maintenance, narrowing the relationship between erudite knowledge and their life experience.

In this context, we cannot teach everything we want. We must select an array of experiences that are more significant within what is being proposed, so that the students have a greater contact with them, that is, define a set of central and essential experiments. We may have a smaller number of equipments but would guarantee more intense and meaningful learning. When we develop a critical spirit we gain in autonomy.

At the end of such a process, it is extremely important that the reports presented are discussed, in order to give feedback to the students. Normally, the activities are finished with the mere devolution of the reports. This way, the students do not have the opportunity to know what are the qualities and shortcomings in this instrument. Teachers must set an appointment with the members of each group to comment on the process. Besides emphasizing the seriousness of the process, it will be an opportunity to discuss other aspects, which are never mentioned, such as what was expected from the group and what was effectively done.

7. Final Considerations

Each year, when we participate in events in the area of teaching engineering we see teachers "with heavy hearts". Many complain of the lack of interest of the students, low grades, lack of commitment, inability to solve problems or work in teams, etc.

On the other hand, the changes proposed seem superficial. Changes in the curriculum grid, removing or adding subjects, changing subjects from one semester to the other, altering their hour load are insufficient. Others believe that the introduction of new software or the development of a new "computerized gadget" for experimental data collection will motivate the students to learn.

This is a complex problem and it would be naïve on our part to believe in one solution. We believe there is a need for real changes in the structure of the classes, altering work procedures being conducted in the classroom. Teachers' lectures are (and will continue to be) essential. However, the students must be prepared for them. Such lectures will be very useful if they fill a gap in students' knowledge. Educational psychology explains that this is most likely to occur when, students are intrigued by a given problem situation and seek some sort of solution. In order to do that, they propose hypothesis and try to prove them, but with unsatisfactory results. In this context the teacher ceases to be a mere transmitter of information to became a coach of "inexperienced researchers".

In order for those ideas to work, one must have a good activity, a problem whose solution is not trivial, which allows several solutions and that students are able to face by proposing and testing hypothesis. To do that, the attitudes, of teachers and students, towards education must also change. And this is probably the greatest difficulty, for in this process, the passive attitudes that have been cultivated for so many years in the academia, will no longer find a place. For the solution of problems, which are similar to the ones found in the industry, it is necessary to have proactive attitudes towards reality.

8. References

BARROS FILHO, J.; SILVA, D.; SANCHEZ, C.G.; ALMEIDA, N.; SILVA, C.A.D.; LACERDA NETO, J.C.N.; ORDONES, J.F. Resgatando no passado novas perspectivas para o ensino de engenharia In: CONGRESSO BRASILEIRO DE ENGENHARIA MECÂNICA, 15, 1999. Águas de Lindóia. Anais eletrônico. Águas de Lindóia: ABENGE, 1999, [CD-ROM].

BAZZO, W. A.; LINSINGEN, I. von; PEREIRA, L. T. do V. O que são e para que servem os estudos CTS. In: CONGRSSO BRASILEIRO DE ENSINO DE ENGENHARIA, 28., 2000, Ouro Preto. Anais eletrônico... Ouro Preto: ABENGE, 2000, 8p. [CD-ROM].

BAZZO, W. A. Ciência, Tecnologia e Sociedade: E o Contexto da Educação Tecnológica. Florianópolis: EDUFSC, 1998. cap.2.

BRASIL - MEC - Ministério da Educação e do Desporto. Proposta de Diretrizes Curriculares dos cursos de Engenharia, 1999. Disponível em: www.mec.gov.br. Acesso em: 18/05/2002.

FERREIRA, R. S. Tendências curriculares na formação do engenheiro do ano 2002. In LINSINGEN, I. von et al. Formação do engenheiro. Florianópolis: EDUFSC, 1999. cap 9, p. 129-142.

FERREYRA, A., GONZÁLEZ, E. M. Reflexiones sobre la enseñanza de la fisica universitaria. Enseñanza de las Ciencias. V. 18, n. 2, p. 189-199, 2000.

FURIÓ, C. Tendencias actuales em la formación del profesorado de ciencias. Enseñanza de las Ciencias. V. 12, n.2, p. 188-199, 1994.

GIL PÉREZ, D. Qué hemos de saber y saber hacer los profesores de ciencias? (Intento de síntesis de las aportaciones de la investigación didáctica). Enseñanza de las Ciencias. V. 9, n.1, p. 69-77, 1991.

HUXHAM, e LAND R. Assigning Students in Group Work Projects. Can Be Do Better than Random? Innovations in Education and Training International:Oxfordshire, v. 37, n. 1, p. 17-22, 2000.

JIMÉNEZ, E., SEGARRA, M. P. La formación de formadores da bachillerato en sus centros docentes. Enseñanza de las Ciencias. V. 19, n.1, p. 163-170, 2001.

LAURIA, D.; ALVES, V. A. O.; MATTA, E. N. O desafio da criatividade na formação e atuação do engenheiro. In: CONGRSSO BRASILEIRO DE ENSINO DE ENGENHARIA, 29., 2001, Porto Alegre. Anais eletrônico. Porto Alegre: ABENGE, 2001, p. FCU – 9 a FCU - 15 [CD-ROM].

LEITÃO, M. A. S. A transição de paradigmas no ensino de engenharia. In: CONGRESSO BRASILEIRO DE ENSINO DE ENGENHARIA, 29., 2001, Porto Alegre. Anais eletrônico. Porto Alegre: ABENGE, 2001, p. MTE – 378 a MTE - 382 [CD-ROM].

LOPES, J. A. A formação do profissional de engenharia à luz das exigências de uma sociedade em constantes transformações: da necessidade de um projeto pedagógico consistente. In: CONGRESSO BRASILEIRO DE ENSINO DE ENGENHARIA, 30., 2002, Piracicaba. Anais eletrônico. Piracicaba: ABENGE, 2002, [CD-ROM].

MAINES, A. Ensino de engenharia – tendências e mudanças. In: CONGRESSO BRASILEIRO DE ENSINO DE ENGENHARIA, 29., 2001, Porto Alegre. Anais eletrônico. Porto Alegre: ABENGE, 2001, p. FCU – 45 a FCU - 50 [CD-ROM].

NIEDA, J.; MACEDO, B. Un Currículo Científico para Estudiantes de 11 a 14 años. Madrid: UNESCO e OEI, 1997.

RAJU, P. K.; SANKAR, C. S. Teaching Real – Word Issues through Case Studies. Journal of Engineering Education. v. 88, n. 4, 1999, p. 501 –508.

ROMPELMAN, O. Assessment of student learning: evolution of objectives in engineering education and the consequences for assessment. European Journal of Engineering Education: Oxfordshire, v. 25, n.4, p. 339-350, 2000.

SALUM, M. J. G. Os currículos de engenharia no Brasil – estágio atual e tendências. In LINSINGEN, I. von et al. Formação do engenheiro. Florianópolis: EDUFSC, 1999. cap 7, p. 107-118.

SÁNCHEZ, C. G.; SILVA, D.; ALMEIDA, N.; BARROS FILHO, J., 2002. Uma Proposta de Ensino de Engenharia de Processos Térmicos e de Fluidos sob Bases Construtivistas. In: CONGRESSO BRASILEIRO DE ENSINO DE ENGENHARIA, 30, 2002, Piracicaba. Anais eletrônico. Piracicaba: ABENGE, 2002, [CD-ROM].

WELLINGTON, R. P.; THOMAS, I. D. Engineering and Business Student Co-operate on Industry Based Projects. Global Journal of Engineering Education: Melbourne, v.2, n.1, p. 33-41, 1998. Disponível em: www.eng.monash.edu.au/uicee/gjee. Acesso em 18 jan. 2003.

ZAINAGHI, G.; AKAMINE, E. G.; BREMER, C. F. Análise do perfil profissional do engenheiro de produção adquirido nas atividades extracurriculares. In: CONGRESSO BRASILEIRO DE ENSINO DE ENGENHARIA, 29., 2001, Porto Alegre. Anais eletrônico. Porto Alegre: ABENGE, 2001, p. APP – 163 a APP - 168 [CD-ROM].

9. Responsibility notice