ENGINEERING AND SOCIETY: WHAT IS WANTED FROM A PROFESSIONAL IN THE XXI CENTURY?

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

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

Jomar Barros Filho
Faculty of Education – Unicamp
Rua Bertrand Russell, 801
Cidade Universitária – Campinas
São Paulo – Brazil – 13083-970
jomarbarrosf@bol.com.br

Norton de Almeida
Faculty of Education – Unicamp
Rua Bertrand Russell, 801
Cidade Universitária – Campinas
São Paulo – Brazil – 13083-970
nortonalmeida@uol.com.br

Caio Glauco Sanchez
Faculty of Mechanical Engineering – Unicamp
Rua Medeleiev, s/n
Cidade Universitária – Campinas
São Paulo – Brazil – 13083-970
caio@fem.unicamp.br

Abstract: In this paper, we will make a critical reflection about the new abilities and competences demanded today from engineering professionals. In this sense, we will present a short historical review on how engineering graduation courses have been built and how technology has been developed. At each time, demands were made over the engineering professionals about certain abilities and competences that were beyond commitment with society. With technological development occurring at an alarming speed in this knowledge society, it is more and more necessary that engineers have abilities and competences such as: ethics, being able to work on multidisciplinary teams, making decisions quickly and, most important, that they acquire a real understanding of social and environmental impacts of their actions.

However, what is seen in engineering graduation courses is that those new abilities and competences are not being completely developed. Inclusion of new disciplines, such as administration, economics or environmental sciences has occurred, in a belief that those disciplines, by themselves, would be able to develop on students the new abilities and competences demanded today for professional practice. Thus, it is not enough to include in curricula such "new" disciplines, dealing with environmental, social and ethical matters, security at work, or others legislations. It is necessary to create teaching activities focusing on real problems, often inside existing disciplines, where pupils are demanded to develop and use those matters in the body of solutions that they will propose to the problems they investigated, which will perhaps contribute to the establishing of relations and developing of ethical and professional responsibilities

Thus, we will discuss the new abilities and competences demanded from future engineers by job markets, focusing on the relations between engineering and society, trying to improve curricula and to achieve more effective education activities.

Keywords: engineering education, skill, competence.

1. Introduction

The engineering art has developed in Europe during the XVI and XVII centuries, due to the need of creating new armaments and the need of security of fortifications. Around that time, the engineers were not much different, in practice, from architects. However, the great impulse of engineering occurred only in the XVIII century (the Light Century), when began the creation of the first schools of engineering (Sacadura, 1999). These institutions were opened to innovations and scientific researches, on opposition to traditional schools of that time which were, in turn, concerned to encyclopedic teaching. Yet, these new schools were more concerned to formation of technocrats that technologists (Bazzo, 1998).

During the First Industrial Revolution, the social and economical role of the Engineering was sketched, since the engineers should try to optimize industrial processes, quantifying the human force and combining this force with other production factors. Thus, we can say that engineers began to need some knowledge about finances and accountancy.

On 20th century, with the end of the First World War, engineers began to have other duties in industrial processes, ascending to unities of supervision and boarding of firms. Thereby, engineers began to require knowledge about administration, management and marketing (Sacadura, 1999).

Later, during the 50's, engineering schools would be successful if theirs students would have acquired knowledge and skills to begin his/her career. This meant that they should be well prepared in sciences, since they worked in industrial-military complex or in aerospace systems, whose focus was in technical expertise (Bucciarelli apud Rompelman, 2000). Moreover, an engineer usually began and finished his career at the same company. So, engineers acted in a less competitive market, with technologies kept in use for a long time (Salum, 1999).

In the second half of the XX century, engineering was diversified with the appearing of countless specialties and new posts where engineers could act on. Thereby, new competences appeared also, demanded by job markets.

At the end of the XX century and beginning of the XXI century, globalization of economy and the increasingly fast technological development demand for engineers a new profile. For contemporary companies, being able to survive in this information society means that they have to become flexible to quickly adapt themselves to changes and dominate technologies that can bring them continually into global competition (Silva, 1999).

Therefore, nowadays it is expected from engineers to be able to identify, formulate and solve engineering problems, often dealing with uncertainness; to be able to work at multidisciplinary and international groups; to know how to communicate efficiently and to defend a proposal, to have professional responsibility and awareness of social, environmental and political impacts of their actions.

However, a first look to the structure of great part of engineering courses and, consequently, to pedagogical practices in classroom, suggests that such skills and competences are not being developed in a complete way (Simon *et al*, 2002; Bazzo, 1998).

Therefore, in this paper we will discuss in a critic way the new abilities and competences demanded nowadays from future engineers, so that they can perform theirs activities in a complete sense. To carry this out, besides a revision in main scientific papers tackling this theme, we will try to make some considerations about engineering teaching, regarding some possibilities of changes.

2. Some abilities and competences and their teaching

In a previous paper (Simon et al, 2002) we affirm that future engineers should have a solid formation and should be able to show a good dominion over fundamental theories, methods and tools widely used in engineering. However, having only a good dominion over traditional contents became a necessary, although insufficient condition to that professional practice (Bucciarelli *et al*, 2000; Rompelman, 2000, 1999; Seat and Lord, 1999).

Several authors (Walkington, 2001; Everett *et al*, 2000) asseverate that the contemporary engineer should be prepared to deal with real problems, identifying, formulating and proposing creative and innovative solutions to hardly formulated problems, leading with large gaps of information, allowing several kinds of ambiguities and managing uncertainties (Bucciarelli *et al*, 2000). Yet, most part of engineering schools persist in a teaching methodology that prioritizes memorization of finished knowledge, not allowing their students to develop their critic reasoning and their creativity. Students, generally, are asked to solve only standard and well defined problems, in a sense that exists only one response and that one is expected by the teacher (Barros Filho *et al,*1999).

This critique is well-founded since, unlike activities that are achieved in graduation disciplines, in most part of real problems does not exist a handbook, study aid or didactic book, where they can find the correct response. It is necessary to be able to, facing a problem, propose explicative hypotheses conducting to the best solution, or in other hands, learning to make decisions (Anwar and Ford, 2001). It is also necessary to build propositions in a more rational way, describing costs and benefits of many options, presenting them to work colleagues in a clear and organized way, besides predicting their possible implications. On the other hand, on the solution of a real problem it is not sufficient to dominate several tools, it is also necessary to know which one is more indicated and advantageous at the moment.

Thus, engineers should possess abilities to develop researching tasks, locating, synthesizing and spreading information, besides extracting results, analyzing and elaborating conclusions. In this aspect laboratory classes also don't contribute to formation of this new engineer. On those classes, students are asked to work with a certain number of prearranged procedures. On other words, for execution of experiments there exists a "cake recipe" that has to be accomplished: you have to set the artifact xx up, you have to measure the parameters yy, and using some well determined equations you have to conclude zz. Then, as those activities deal only with closed problems, engineering students are not solicited to make qualitative analysis, or to propose and testing their hypothesis (Sánchez *et al*, 2002).

With technological development occurring in an alarming speed, mainly in information processing area, several authors (Hozumi *et al*, 2000; Nguyen and Pudlowski, 1998) affirm that engineers have to dominate basic computational tools, being able to critically analyze models used in engineering study and practice. Engineers should be competent to use, dominate, improve and produce technologies during their whole professional life. However, an analysis of graduation courses shows that the educational milieu seems to be distant from technological development (Moraes, 1999). Computational disciplines mostly develop specific skills on several tools, teaching, for instance, how to create a software for a certain analysis in engineering, rarely considering the impact of errors and limitations of those programs

(Lowe *et al*, 2000). Therefore, they don't recognize the range of tools that students will work with in their professional lives is bigger than that. With fast advancements in this area, tools learned in the beginning of a course will have little utility around graduation time. Thus, students should, beyond learning how to use tools, be able to critically evaluate which one and when to use those tools to solve their problems (Bucciarelli *et al*, 2000).

Nowadays, it is expected from a professional of engineering area to be able to work on multidisciplinary groups (Wankat, 2001; Rompelman, 2000), since problems have become more and more complex, demanding professionals of several areas. For this teamwork to be effective, their members have to be able to communicate effectively, on oral, writing and graphical ways, and they should be able to present information on a significant and appropriate way, and to be able to articulate, communicate and defend a proposal (Sousa, 2000). Moreover, good interpersonal skills also contribute to help teamwork (Nguyen and Pudlowski, 1998).

On an era when borders between countries have been reduced and research work have occurred in several parts of the world, linguistic barriers must be overcome. Today's Brazilian engineers, having to work in this global market with international teams, need some knowledge about other languages, mainly English and Spanish (Silva, 1999). However, having only a language knowledge is not enough to work on international teams. To have competence on international and intercultural communication, engineers should have some learning about people's culture on regions around the world where he/she may work, including international business issues (Crnkovic and Santos, 2002; Nguyen, 1998). He/she should know, too, historical evolution of new technologies, including the time and effort needed for it (Bermudez, 1999), he/she should broadly understand other points of view and cultures and he should know how the organizational culture on that work has developed and established. In Nguyen and Pudlowski (1998) word's: *"understanding of cultural and environmental aspects of other nations are key factors for international succeeding".*

Despite these needs, major part of engineering courses give little or no importance to disciplines like English, Spanish, history of technologies and sciences, Sociology, Anthropology or History. Sometimes, those disciplines are offered as electives, not being part of obligatory curriculum.

Nevertheless, some other disciplines have been included on the engineering curricula on last years. Among them, we can mention administration, economics, law studies, environmental sciences and ethics. As we said previously, after the end of First World War, activities of engineers inside enterprises began to be modified. Beginning to occupy leadership and management positions, "new" engineers felt necessity to achieve knowledge about administration, business management, marketing and logistics. From those days on, the ability to administrate materials, people, costs and time, to coordinate, supervise and manage things, to have knowledge on quality management, and capacity to lead people, became primordial to occupy a more elevate position (Hozumi and Hozumi, 2002; Borrás *et al*, 2000). To get this, it is necessary to dominate and apply the pertinent legislation and to know security norms of work, too (Querino e Borges, 2002).

Moreover, several authors affirm that is essential, nowadays, that the engineer should have some knowledge on economic and financial issues and that he/she should know how to assess the economic viability of engineering projects (MEC, 2002). He/she should have the skill to rationally manage resources, combining them, as well as to analyze and control costs. He/she should be able to understand international social-economic problems, and to understand the functioning of international market, changing constantly today (Pessôa and Marques Filho, 2001).

In this beginning of the XXI century, society demands professionals engaged with environmental and social issues. In this way, it is expected that engineers know how to analyze and value social and environmental consequences caused by technological development (Pereira *et al*, 2000). It becomes necessary, so, that they have an attitude of awareness and sensibility to understand environmental problems of each country and their relationship with the rest of the planet, to dominate issues like sustainable development and ecology, and that they know to develop projects in this area and understand the influence of them on their decisions (Walkington, 2001). In this way, the contemporary engineer should be able to propose environmental solutions or minimize dangers for environment or society, in general, resulting from their actions (Nguyen, 1998).

Thus, more and more, it is demanded from the engineer to be conscientious about practice and ethics codes that govern his/her profession, as well as have a professional, social and environmental responsibility (Encinas, 2000).

Besides that, we observe the inclusion of these disciplines in curricula, in a belief that those disciplines, by themselves, will be able to develop in students these new abilities and competences demanded today on their profession. Thereby, it is not enough to include in curricula disciplines dealing with management, economic, environmental social and ethics issues. It is necessary to create new teaching activities dealing with real problems, often in already existent disciplines, where students can be requested to develop and use those themes on solutions that they will propose to investigated problems, which may contribute for the student to establish relations and develop professional and ethic responsibilities.

Because of great competitiveness between enterprises, the capacity to deal with stress, fault or rejection also became important, since employment is no more guaranteed and the pressure for products with quality became higher (Borrás *et al*, 2000). Thus, engineering courses should prepare their graduates for a diversity of employs, should it be in a big corporation with global action, or in a small enterprise, or in a consultancy firm and to be engaged on different posts.

Moreover, it could be seen that, in Brazil, a growing number of students are starting her/his own business. And herewith our graduate people needs to develop a entrepreneurial, systemic and generalist vision in multidisciplinary level, so they can understand and identify work opportunities (Loureiro *et al*, 2000). Thus, engineers should be able to respond quickly to challenges, achieving and processing knowledge quickly, and they have to have flexibility to adapt themselves to new market needs and to new technologies (Rompleman, 2000). In Salum's (1999) words it's necessary: *"to give them conditions to realize changes and to structure themselves, quickly, in a new paradigm"*.

Therefore, Universities cannot claim to give any warranties that the student will be kept actualized on all of his/her professional life. It is waited from Universities to give elements for self-learning, or in other words, "to learn how to learn" (Enemark, 2002). Contemporary engineering professional should have autonomy to keep himself actualized, and to achieve knowledge during all her/his professional life.

3. Final considerations:

Today, reality places new demands for engineering teaching. Professionals graduated on a traditional teaching, based essentially on transmission and reception of knowledge, begin not to have the profile requested by the contemporary society.

In this paper, we try to present a set of new abilities and competences that became part of this new repertory. Thus, skills like working on multidisciplinary teams, knowing how to solve real problems, having professional responsibility, understanding social and environmental impacts of their actions, besides keeping themselves constantly updated and having flexibility to self-adapt to changes, need to start being integral part of engineering courses.

Fact is: we are still "crawling" on this area, thereby there are only a few papers trying to achieve concrete propositions on changes (Lezana, 1999). According to Bazzo (1998): *"In spite of good intentions involved in dealing with those issues, the medicine adopted, almost always the same with little alterations, continues to show inefficacy. Countless, and always present, remodeling of curricular grades, constant alterations of time scheduling, demand for diminution of expositive-type classes and re-equipment laboratories, in an isolated way, didn't have been good solutions. When one realizes the inefficiency of such treatment, he grows the doses, but the illness remains the same"*.

Moreover, there is no clarity about how to teach these abilities and competences. The fact is that the way in which disciplines are structured seems not to be reaching these objectives. Only expositive classes, where students keep passive attitudes facing knowledge, don't allow approaches that are nearer from reality. Thus, possibility to work with more opened problematic situations, in a more investigative way, achieving qualitative analyses, proposing and testing hypotheses, working in collaborative teams, testing the limitations of used models, deciding what model and what theories should be used, etc, is lost.

These ideas show possible ways that should be investigated. Therefore, to give subsidies for our graduates to arrive on the job market with those abilities and competences, we need to develop teaching activities that be able to intellectually challenge our students. Such task is not an easy one, but in face with the new requirements imposed by reality, such goal must be pursued.

4. References

Anwar, S. and Ford, P., 2001. Use of a case study approach to teach engineering technology students. International Journal of Electrical Engineering Education, vol. 38, n.1, pp. 1-10

Araújo, H. N.; Franco, E. M., 2002. Metodologia de pesquisa *versus* introdução à engenharia civil: um exercício prático. Proceedings of XXX Congresso Brasileiro de Ensino de Engenharia, Piracicaba, Brasil. [CD-ROM].

Barros Filho, J.; Silva, D.; Sánchez, C.G; Almeida, N.; Silva, C.A.D.; Lacerda Neto, J.C.N.; ORDONES, J. F., 1999. Resgatando no passado novas perspectivas para o ensino de engenharia. Proceedings of XV Congresso Brasileiro de Engenharia Mecânica, Águas de Lindóia, Brasil, pp.113 – 113.

Bazzo, W. A., 1998 Ciência, Tecnologia e Sociedade, e o Contexto da Educação Tecnológica. EDUFSC, Florianópolis, Brasil.

Bermudez, J. C. M., 1999. A educação tecnológica precisa de uma política. In Linsingen, I. von et al. Formação do engenheiro. EDUFSC, Florianópolis, Brasil, pp. 67-76.

Borrás, M. A A; Batalha, M. O.; Costa, M. A. B., 2000. Formação de engenheiros no agronegócio brasileiro: avaliação do perfil de profissionais ofertado para o mercado de trabalho nacional. Proceedings of XXVIII Congresso Brasileiro de Ensino de Engenharia, Ouro Preto, Brasil, 10p. [CD-ROM].

Bucciarelli L. L., Einstein H. H., Terenzini P. T. e Walser A. D., 2000. ECSEL/MIT Engineering Education Workshop'99: A Report with Recommendations. Journal of Engineering Education, vol.89, n.2, pp.141-150.

Crnkovic, L. H.; Santos, F. C., 2002 A Cultura organizacional: um diferencial na formação do engenheiro. Proceedings of XXX Congresso Brasileiro de Ensino de Engenharia, Piracicaba, Brasil. [CD-ROM].

Encinas, J. I., 2000. Grade curricular do engenheiro florestal para o perfil 2020. Proceedings of XXVIII Congresso Brasileiro de Ensino de Engenharia, Ouro Preto, Brasil, 5p. [CD-ROM].

Enemark, S., 2002. Innovation in Surveying education. Global Journal of Engineering Education, vol.6, n.2, pp. 153-160. Available in: www.eng.monash.edu.au/uicee/gjee. Access in 18 jan. 2003.

Everett, L. J.; Imbrie, P. K. e Morgan, J., 2000. Integrated Curricula: Purpose and Design. Journal of Engineering Education, vol. 89, n. 2, pp. 167-175.

Hozumi, C. R. J.; Gouvêa, C. A.; Leal, M. G. F., 2000. As transformações no mundo do trabalho e sua implicação nos cursos de engenharia. Proceedings of XXVIII Congresso Brasileiro de Ensino de Engenharia, Ouro Preto, Brasil, 10p. [CD-ROM].

Hozumi, C. R. J.; Hozumi, V. M. R. G., 2002. Questões ambientais e atuação do engenheiro gestor. Proceedings of XXX Congresso Brasileiro de Ensino de Engenharia, Piracicaba, Brasil. [CD-ROM].

Lezana, A G. R. A educação tecnológica e a tecnologia na educação. In Linsingen, I. von et al. Formação do engenheiro.EDUFSC, Florianópolis, Brasil, pp. 197-205.

Loureiro, F. C. C. L., 2000. Reflexão crítica sobre a prática docente atual nas engenharias. Proceedings of XXVIII Congresso Brasileiro de Ensino de Engenharia, Ouro Preto, Brasil, 4p. [CD-ROM].

Lowe, D. B.; Scott, C. A. e Bagia, R., 2000. A Skills Development Framework for Learning Computing Tools in the Context of Engineering Practice. European Journal of Engineering Education, vol. 25, n. 1, pp. 45-56.

MEC, 2002. Diretrizes Curriculares nacionais dos Cursos de Engenharia. Parecer CNE/CES 1362/2001. Diário Oficial da União, Conselho Nacional de Educação/ Câmara de Educação Superior, Brasília, Brasil. Seção 1, p. 17. Available in: www.mec.gov.br.

Moraes, M. C., 1999. O perfil do engenheiro dos novos tempos e as novas pautas educacionais. In Linsingen, I. von et al. Formação do engenheiro.EDUFSC, Florianópolis, Brasil, pp. 53-66.

Nguyen, D. Q., 1998. The Essential Skills and Attributes of an Engineer: A Comparative Study of Academics, Industry Personnel and Engineering Students. Global Journal of Engineering Education, vol. 2, n. 1, pp. 65-76.

Nguyen, D. Q.; Pudlowski, Z. J., 1998. The perspective of African Students on Environmental Education in Engineering Courses in the Republic of South Africa. Global Journal of Engineering Education, vol.2, n.2, pp. 169-176, 1998. Available in: www.eng.monash.edu.au/uicee/gjee. Access in 18 jan. 2003.

Pereira, L. T. do V.; Bazzo, W. A.; Linsingen, I. von., 2000. Uma disciplina CTS para os cursos de engenharia. Proceedings of XXVIII Congresso Brasileiro de Ensino de Engenharia, Ouro Preto, Brasil, 8p. [CD-ROM].

Pessôa, M. S. P.; Marques Filho, M. P. A., 2001. Jogos de empresas: uma metodologia para o ensino de engenharia ou administração. Proceedings of XXIX Congresso Brasileiro de Ensino de Engenharia, Porto Alegre, Brasil, pp. NTM – 137 a NTM - 144 [CD-ROM].

Querino, R. A.; Borges, M. L., 2002. As ciências humanas e o currículo por competências na engenharia civil: o projeto político-pedagógico da Universidade de Uberaba. Proceedings of XXX Congresso Brasileiro de Ensino de Engenharia, Piracicaba, Brasil. [CD-ROM].

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

Sacadura, J. F., 1999. A formação dos engenheiros no limiar do terceiro milênio. In Linsingen, I. von et al. Formação do engenheiro.EDUFSC, Florianópolis, Brasil, pp. 13-27.

Salum, M. J. G., 1999. Os currículos de engenharia no Brasil – estágio atual e tendências. In Linsingen, I. von et al. Formação do engenheiro. EDUFSC, Florianópolis, Brasil, pp. 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. Proceedings of XXX Congresso Brasileiro de Ensino de Engenharia, Piracicaba, Brasil. [CD-ROM].

Seat E.; Lord S. M., 1999. Enabling Effective Enginnering Teams: A Program for Teaching Interaction Skills. Journal of Engineering Education, vol. 88, n.4, pp.385-390.

Silva, D. da. O engenheiro que as empresas querem hoje. In Linsingen, I. von et al. Formação do engenheiro. EDUFSC, Florianópolis, Brasil, pp. 77-88.

Simon, F, O.; Barros Filho, J.; Silva, D.; Sánchez, C. G., 2002. Algumas tendências sobre habilidades e competências exigidas nos cursos de graduação em engenharia. Proceedings of XXX Congresso Brasileiro de Ensino de Engenharia, Piracicaba, Brasil. [CD-ROM].

Sousa, A. C. G., 2000. Uma estrutura curricular flexível e dinâmica Anais do XXVIII Congresso Brasileiro de Ensino de Engenharia, Ouro Preto, Brasil, 8p. [CD-ROM].

Thomas, I. D.; Hadgraft, R. G. e Daly P. S., 1997. Issues Related to the Use of Peer Assessment in Engineering Courses Using a Problem-Based Learning Approach. Global Journal of Engineering Education, vol. 1, n.2. Available in: www.eng.monash.edu.au/uicee/gjee. Access in 18 jan. 2003.

Walkington, J., 2001. Designing the Engineering Curriculum to Cater for Generic Skills and Student Diversity. Australasian Journal of Engineering Education, vol. 9, n. 2, pp. 127-135.

Wankat, P. C., 2001. Efficient, Effective Teaching. Chemical Engineering Education, vol. 35, n.2, pp. 92-95.