Interdisciplinarity in higher education - natural science electives for engineering students

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ABSTRACT: For more than 10 years the Polish Ministry of Higher Education has stressed the implementation of humanities or natural science courses into engineering studies curricula. These courses mostly are electives (optional courses). The humanities courses, as implemented into the engineering study plans, have produced in recent years: an increased number of interdisciplinary science research projects; interdisciplinary diploma projects; engineering research and projects in collaboration with institutions from non-engineering-branches; and even interdisciplinary study curricula. It has also resulted in students' personal development and individual talents and hobbies. In this paper the authors discuss the role of humanities and natural science courses in engineers' education; examples, both good and bad; and the opinions of students and teachers.

INTRODUCTION

Since the 1990s, with new concepts and regulations for higher education in Poland the updated study plans have been discussed. These have brought many important changes and demands. Some changes were a result of European Commission demands, some because of a necessary *modernisation* of traditional types of higher education in Poland. Most of the important changes in engineering education were: the implementation of two levels of education - engineering and masters of science; and more stress to be put on training and practical studies. Since then, many complaints and enthusiastic comments have appeared. The passing of time since the 1990s has verified realisation of the newly implemented ideas. Two levels of education (engineer, and masters of science) have been implemented in almost every higher education institution in Poland.

HUMANITIES COURSES IN STUDY PLANS

Since the 1990s, humanities courses have been implemented as a necessary element of technical study. These requirements were made by the Ministry of Higher Education. The Ministry stated the minimal demands (study standards) for each course of study. It should be pointed out that the idea of the *humanisation of engineering study* comes from the early 1960. After World War II, engineering studies were generally *dehumanised* - in Poland, too. Professional courses were stressed, and the humanity courses (present in the curricula before) were found to be old-fashioned and then abandoned.

One of the earliest ideas of humanisation of technical curricula appeared in the 1960s, thanks to Professor Bugiel at AGH University of Science and Technology in Kraków, and it was also accepted at Warsaw Polytechnic. Courses dedicated to sociology, psychology, management and interpersonal relations, were implemented in the curricula of engineering study. In 1995, the idea of creating a *Department of the Humanities* was raised in AGH in Krakow, and in 2001 the *Social Applied Sciences Department* was created there [1][2].

Dziewulski expressed an opinion that the most important subject in humanities studies is philosophy, because it deals with creating the human spirit, in such things as truth, goodness and beauty [3]. He represents an opinion that says only philosophy is the *humanities science*. Other courses/sciences also could be treated as humanities science if they correspond to philosophy - contrary to para-humanities studies (or courses). The *para-humanities* courses only deal with the *statistics of social life*.

Courses in the Humanities in fact influence personality, and intellectual development of society. They are creating *people criteria and moral estimations*. They also teach how to live in accordance with nature. Studies in Humanities develop intellectual sensitivity in the youth, leading to distinguishing between values and valueless things (such as

ideas, especially in pop-culture and the mass-media) [2]. At present, the humanisation of engineering studies does not only mean the contents of courses or curricula, but also methods of teaching and studying [2][3]. Due to the new higher education law and all regulations beginning from 1997, higher vocational schools were created in Poland, and their regulations and study standards were accepted by the Ministry.

The model for higher vocational schools in the beginning was the *Hochschule-like* system, which is similar to that in Germany or Austria. But more stress was put on practical studies. It was changed in Poland in 2001, and the trend for unification of curricula was observed. The same regulation for all types of higher educational institution was implemented. It corresponds to the European Union commission demands for a European higher educational environment, the Bologna Process and the implementation in every EU country of two levels of higher education (engineering/bachelors followed by masters), as well as EU recognition of higher education. Demands, study standards, law and regulation are now the same for all higher educational institutions in Poland. It means these are the same for universities, polytechnics, colleges, higher vocational schools, academies, schools of art, etc, despite being private or state (the newest project in Higher Education Law is being discussed now in Poland, having started in March 2010). Generally, there are observed trends for unification of higher education in all EU countries.

At present, in Poland, for every engineering study course, as well as for most of the non-humanities study courses, the number of hours dedicated to *humanities courses* must be planned into the study curricula. Sometimes it is described in the standards that such blocks of courses/electives should include particular subjects (as, for example, ethics for medical or healthcare courses). For some engineering courses, requirements may be management, law or natural science. Such courses should be offered by the university as optional, and it should be the student's decision as to what he or she prefers. The institution responsible for regulations on higher education is the Ministry of Higher Education. The institutions responsible for control, if the regulations are implemented properly, are the Ministry of Higher Education and the Accreditation Commission.

INTERDISCIPLINARITY IN EUROPEAN UNIVERSITIES

Present demands for professional engineers mean the humanities courses in the study curricula are not enough. People in accordance with market labour demands are seeking interdisciplinary engineering or masters courses [4][5], as well as interdisciplinary postgraduate courses [6-8]. More than 60% of European universities questioned declared they offer interdisciplinary courses for postgraduate curricula [7]. In between the group of questioned were traditional universities, technical universities and subject-orientated universities (more than 50 institutions from 21 countries). Most interesting was the research on the subjects with a leading role in existing interdisciplinary postgraduate curricula. The authors found that computer science led, followed by electrical engineering, mechanical engineering, economics and logistics, and business informatics.

It was found that, contrary to what is offered (in postgraduate curricula), students are most interested in the postgraduate/masters curriculum consisting of IT (16%), management (11%), biomedical/bio-computing (10%), economics (10%), electrical engineering (9%), environmental studies (8%) and applied sciences (8%). Other suggested courses were chosen by fewer than 7 % of the students, and the ones students found less attractive were mechanical engineering, and the bank industry [8]. These observations meet employers' demands. Research dedicated to graduate skills and competencies necessary in the modern labour market show that the most important are *capacity to learn* and *problem-solving skills* [9]. It should be pointed out that, for employers, *basic general knowledge in the field of study* is much less important than *ability to work in an interdisciplinary team*, *ability to communicate with non-experts in the field*, *concern for quality*, and *ethical commitment!*

NATURAL SCIENCE ELECTIVES FOR ENGINEERING STUDENTS AT *PWSZ TARNOW*

Several courses are offered to students of engineering courses at the Higher Professional State School in Tarnów (PWSZ in Tarnów). Incorporated into the curriculum for IT are courses dedicated to law, copyright and sociology. In the curricula for electronics, materials engineering, and electrical engineering are courses dedicated to sociology, psychology, law, philosophy and natural science (as optional or elective courses). For the natural sciences, courses dedicated to *Ecology* are offered at present, as well as *Ecology and environmental management*.

ECOLOGY FOR STUDENTS OF ENGINEERING

Ecology courses for engineering students are offered in the summer semester. This arrangement makes it possible to organise at the end of the semester, some excursions to, as well as exercises in, nature.

In 2008, first-year students were asked, anonymously, to answer several questions. The answers revealed that most of the students have no basic knowledge of biology and ecology. They declared that recently they had biology and chemistry in primary school/gymnasium (and they do not remember much). They had no lectures in high school dedicated to biology, chemistry or ecology. About 3% to 5 % of the students happened to finish lyceum or high school (as a technical high school dedicated to environmental protection) and declared a *good level of knowledge* in the natural

science subjects. All of the students were interested in the ecology courses for engineers. This might suggest the teachers' interests influenced the students.

The ecology course for engineers was organised into lectures/or tutoring (15 hours per semester); or lectures plus tutoring (30 to 45 hours per semester). Even if the course was made up of only lectures, it was organised more in the manner of seminars: the students were frequently questioned, and pushed to discuss and solve a problem. Also one or two lecturing hours were dedicated to excursions (even then it was just 15 hours of meetings in total). The main educational aspects of the course, *Ecology*, for engineers were to:

- present the main problems that may happen in engineering, caused by environment (with good and bad examples); impact of the people on the environment, as well as impact of the environment on people;
- improve the knowledge of dangerous (for human beings) physical and chemical factors in the natural environment, and especially in the work environment;
- present the case that engineering is mainly applied science;
- improve general knowledge of the natural environment.

Also, the course conveys the general idea that science and engineering may be interesting and even funny, and gives a chance for students to develop individual skills and hobbies, as well as to present their individual achievements. Subjects dedicated to the main problems that could happen in engineering (caused by the environment) are electrical engineering, mechanical and civil engineering. This is because large construction projects and the important impact of engineering investments/technologies on the environment are within these areas of the profession. When students recently were asked to solve a problem, examples were arranged to show that, usually, it is possible to solve the problem simply or cheaply (or just not to cause the problem in the first place).

The main aspects of the part of the course dedicated to physical and chemical factors in the natural environment, and especially in the work environment, were: toxins and poisonous substances; heavy metals; electrical and magnetic fields. Also, engineering problems, such as *sustainable development*, *clean production*, and the necessity to use *best available technology*, were presented where there was an adequate knowledge base.

Students were interested also in applying engineering to medicine and environmental technologies. At present, it is one of the most highly developed applications of the electrical, electronics, material sciences and IT technologies. Most development seems to be taking place in the medical branches of these fields. For example, in the engineering course, examples of interdisciplinary collaboration and application of engineering technologies and researches in many branches are discussed. Some of them are the visualisations of the human body and the physiological processes using new techniques and technologies [e.g. Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI), etc].

Also, important subjects for the organised excursions are metrology and automation. Students recently were given the opportunity to visit plants for waste disposal, waste water disposal and dangerous wastes combustion. They observed measurements by hand and automatically; monitoring systems; automation systems in the plants; engines; pumps; and all equipment. Materials engineering students also had the opportunity to obtain knowledge about dangerous substances, chemical processes and laboratory work.

The part of the course dedicated to improving general knowledge of the natural environment dealt with plants and/or animals found in the natural environment of our region. Such tutoring can be organised outside the university, in the natural habitat, and it offers an opportunity for close contact with nature. Such activities were also organised during an excursion to the Educational Ecological Centre in Polichty, which is 40 km from Tarnów. Here, the tours are guided by professionals (Figure 1).

Figure 1: Electrical engineering students at the Educational Ecological Centre in Polichty, June 2008.

To make observation in nature easier, birds can be attracted by playing a CD recording of one of the species singing. For proper bird recognition, the vocalisation of some species might be *learnt by heart* by the observer (student). This is not easy and in the studying process students might use visualisation of bird vocalisation. The professional programs for signal visualisation, such as *CoolEdit*, *CoolEditPro*, *Adobe Audition* are applied. These are applied professionally for signal analysis (for example, Fast Fourier Transform analysis) (see Figure 2).

Students may later use the programmes for professional purposes or as a hobby (e.g. to create an MP3, or mix their own compositions). Also, MATLAB might be applied during the course for visualising the signals. This is the program mostly used for professional and educational purposes in engineering studies. Such knowledge achieved in the ecology course could be fruitful for the other professional engineering courses.

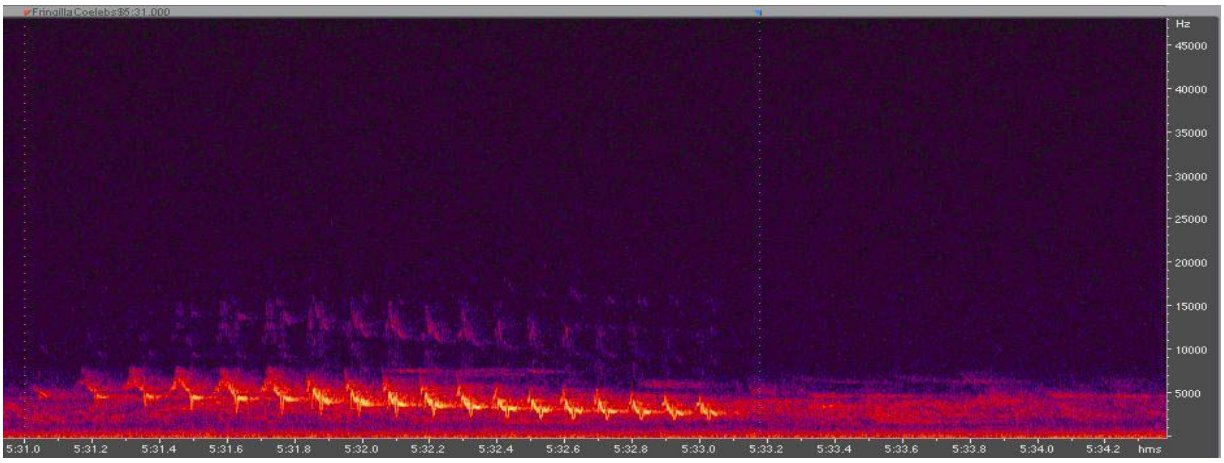

Figure 2: Exemplary visualisation in the *Adobe Audition* programme (Fast Fourier Transform analysis) of vocalisation of the chaffinch, *Fringilla coelebs.*

ECOLOGY WITH ENVIRONMENTAL MANAGEMENT FOR STUDENTS OF ENGINEERING

The aims, as described for the *Ecology* course for engineers, are the same. But the new aspects are:

- knowledge about the present international, European Union and national law and environmental regulations within engineering;
- environmental standards (as ISO 14 000);
- environmental management basics;
- problem-solving activities.

Several tutored classes for the electrical engineering students were dedicated to renewable energy. The students worked in groups and had to prepare oral presentations on given types of renewable energy technology. They also had to prepare a Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis on their subject. These two marks, with the final tests mark (covering the whole course), consist of the total final mark to pass the course.

ADDITIONAL ASPECTS FOR *THE HUMANITIES* COURSES/ELECTIVES

Humanities courses, especially those dedicated to the natural sciences for engineers, should, as was mentioned earlier, give the general feeling that science and engineering may be interesting and even funny; offer the chance to develop individual skills and hobbies; as well as having influence on personality, and the intellectual development of society. During the *humanities* courses, students do not feel so pressured. Sometimes they find these courses are a good opportunity to present individual skills and hobbies.

Every activity and extra knowledge (sometimes not connected with the studied profession/subject) might be of great value in a future professional career. Students like to discuss, present a manual skill (such as drawing, painting and constructing), or express imagination (for example, during a brainstorming session as one of the *management activities*). Such skills and the understanding of their importance are of great value in a future professional engineering career. These are fruitful for professional interdisciplinary work, applied work, and communication with non-professionals in the field.

CONCLUSIONS

Humanities courses are a necessary element of the engineering curricula. Humanities knowledge plays an important role in personal development, as interdisciplinary skills and competencies of engineers' universities enlarge numbers and

fields of the humanities courses in the engineering curricula. The number offered in the EU interdisciplinary and multidisciplinary masters and postgraduate courses, for example, has increased.

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