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Cooperative problem-based learning approach in environmental engineering studies

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Abstract. Market requirements and competition in the job market set the necessity for an engineering specialist capable of not only analysing the theory of a situation but also able to transfer theoretical knowledge into practise. In order to lessen the degree to which students are isolated from those real-life situations with which they will be working with daily upon graduating, it is important to integrate a problem-based learning approach based on the study course. The paper describes a Cooperative Problem-Based Learning Approach used in Environmental Engineering Studies and provides progress analysis about 8 years of experience in organizing the course.

Key words: environmental management systems, teaching method, Environmental Science, study course, students.

INTRODUCTION

Improving engineering education is essential to ensure development of a sustainable society which has an appropriate balance among social security, favourable environmental conditions and economic progress. An environmental engineering education should develop professionals who can make changes to their environment with negligible negative impact. As discussed by Maghugj et al. (2006), the role of the university can be evaluated through the production of knowledge and impact on society. Sustainability is an issue which presents more challenges to engineers – the necessity for a holistic view on problems requires a more profound understanding of cross-cutting issues. A more diverse understanding of various problem solving techniques gives the engineering more flexibility to choose application appropriate to any given situation. The integrated approach which will be required in the workplace needs, thus to be mirrored during the study period of the engineering sciences (Eriksson & Mäkitalo, 2013).

According to Ghaffari and Talebbeydokhti (Ghaffari & Talebbeydokhti, 2013), nowadays universities can provide theoretical and special courses, academic programs and laboratory works to maximise the students' involvement with real industry players and real projects. Nguyen & Hens, (2013) suggest that environmental engineering education is better delivered through specialised programmes rather than as part of larger civil engineering programmes. It is argued that within specialised programmes, it is possible to give appropriate attention to the significant issues, relevance and

characteristics of environmental engineering. Another source (Kapranos, 2013) adds the importance to consider the ethical behaviour of preparing professional engineers which is perhaps even more complicated in reference to environmental engineers since these have a moral obligation not only to society (social responsibility), but also to the state of the environment (strong ecological responsibility). Development of Environmental Science Programmes in Latvia is described in detail by Kļaviņš, (2008), Kļaviņš & Zaļoksnis, (2009) and Blumberga et al. (2010).

Cooperative Learning (CL) is an interactive learning process designed to establish well-suited and sustainable groups for learning with interdependent members. The groups cooperate together to complete tasks (Adi et al., 2012). CL learning looks to achieve interdependence and accountability in the students on the individual level (Yusof et al., 2012).

Several studies (Leola et al, 2011; Rasmussen, 2012; Mintz & Tal, 2013; Zint et al., 2013;) found that there are gaps between environmental, economic and social knowledge and that students do not consider that their studies have contributed a lot to the views they hold on the environment. This indicates the need to excel practise-based learning models during studies to bridge the gaps students identify among the various disciplines one needs to apply for sustainable approaches and to ensure that studies have a positive impact on shaping their attitudes and knowledge.

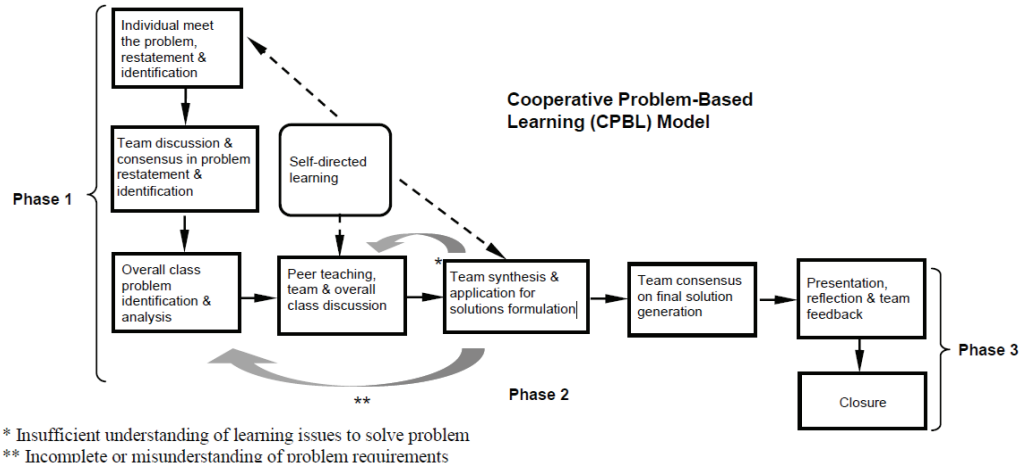

Figure 1. The Cooperative Problem-Based Learning (CPBL) Framework (Mohd-Yusof et al., 2011).

Case Model educational approach is a good way to focus on one issue or problem. It is a positive way to explore complex issues and give time for their deep analysis by the students (Razali & Zainal, 2013). Similarly, the Problem-Based Learning (PBL) approach deals with a real problem and it helps to improve problem-solving and meta-cognitive skills (Yusof et al., 2012; M. Sánchez et al., 2013). According to experience of the University of Sheffield, Department of Materials Science & Engineering, *Use of a Research Role Playing Exercise to Fast Track the Development of Early Stage PhD Researchers* (Kapranos, 2013), role play and simulation exercises help to develop various skills in students such as time management, project planning, literature

analysis, personal relationship building, and others. As described by Tan (Tan, 2009) the PBL approach helps in advancing skills in a multi-disciplinary approach and pushing students to expand on their existing skills.

The Cooperative Problem Based Learning CPBL also includes principles of problem-based learning and working in teams. It also applies a multi-disciplinary, over-arching approach to problem-solving to produce professionals who can better grasp complex interrelationships between environmental, economic and social issues (Mohd-Yusof et al., 2011).

This study integrates CPBL based learning method in the *Environmental Management* course of an engineering science programme by integrating knowledge on developing an environmental management system with real practical experience in working with an actual, working industrial company. The objective of the offered teaching model is to improve the quality of learning through a variety of approaches that the students engage in as part of the process: desk review of legal environmental and sector-specific regulations, rapid assessment of environmental risks from a short site visit, analysis of environmental risks through rough calculations, prioritization and discussions. The students in parallel build interpersonal skills on team work, negotiation skills with real business people from the companies with which they cooperate and a larger appreciation for the challenges in putting environmental priorities against those of social, economic and other competing concerns.

METHODS AND MATERIALS

Implementation of the CPBL based learning method is carried within the 'Environmental Management Systems' course (4.5 ECTS). The course on Environmental Management Systems is implemented as part of the two year Master study programme 'Environmental Science' (120 ECTS) of the Riga Technical University and it is defined as a compulsory study course. The main objective of the course is: to acquire theoretical knowledge on the principles of environmental management systems according to international principles (EMAS and ISO 14001) and practical experience on its application in Latvia, Europe and elsewhere; to acquire practical skills on resolving environmental issues on the municipal level and in the private sector. General themes included in the study course on Environmental Management Systems are given in Table 1.

The plan of the course offered includes the development of such skills and competencies as:

- Work groups – distribution of roles and responsibilities within the group, networking skills;
- Critical analysis of information – assessment of the legislative and other regulatory acts and frameworks, analysis of documents provided by the companies, data credibility evaluation;
- Integrated approach in solving problems – application of knowledge and skills acquired from other courses, situational analyses, optimization of the company's facilities (see Fig. 2);
- Development of certification documentation – use of language and forms, balance of company interests (in regard to financial, human resource concerns and

capacities) with environmental, use of language and forms, development of procedures, protocols, etc.;

- Presentation skills – development of training programme, as well as actual training of company representatives; presentation and argumentation skills in presenting results to the company.

Table 1. General themes included in the study course on Environmental Management Systems

Topics	Teaching method	Academic hours spent
Introduction to EMS, main elements of ISO 14001	Lecture	2
Environmental aspects	Lecture and practical class	4
Environmental policy	Lecture	2
Legal acts and other requirements	Lecture and practical class	4
Evaluation of aspects	Lecture	4
Resources, roles and responsibilities	Lecture	4
Introduction with a case industry	Site visit and lecture	4
Cooperative task at the case industry: identification of environmental aspects	Site visit and practical class	4
Group presentations and discussions on results	Practical class	4
Checks and monitoring. Internal audit	Individual work	4
Management review, Comparison of separate and integrated EMS and final evaluation of the situation in the case company	Practical class	4
ISO certification audit. Analysis from the experience of other companies	Lecture and practical class	4
Training on EMS conducted in the case company. Presentation of the EMS manual to the case company.	Practical class	4

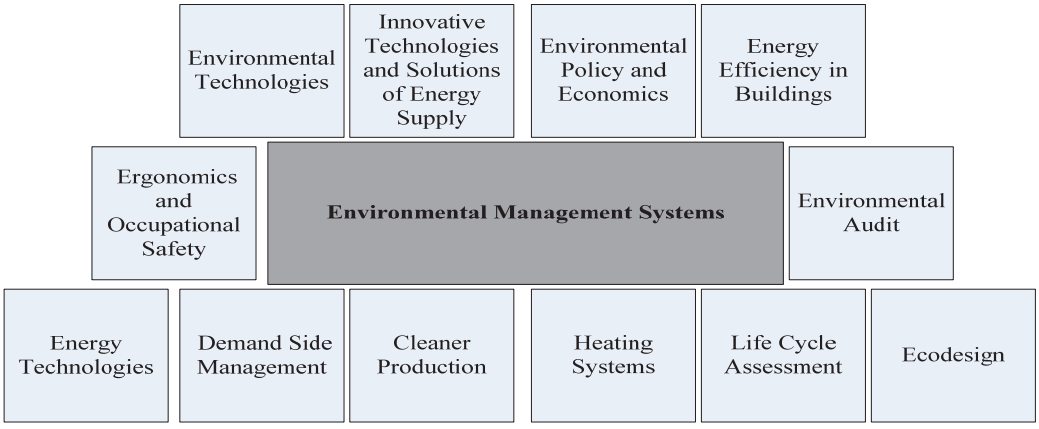

Figure 2. Important courses used in environmental management skills.

Implementation of the presented CPBL based learning method in the Engineering Science programme includes two consequential phases:

- 1st phase: development of the study concept and testing of the method internally within the institution (preparation phase);
- 2nd phase: application of the method in external enterprises (method implementation and improvement phase);
- 3rd phase: application of conceptual understanding of environmental management systems from the company-level to the national, regional and global-levels.

RESULTS AND DISCUSSION

The research results are reflected in three, previously defined development stages of study methods, the experience of which was gained in the period from 2006 to 2013.

1st phase: One of the first environmental management programmes developed in accordance with the ISO 14001 standard was in 2007 with the development of an environmental management system for the Institute of Energy Systems and the Environment (IESE) of the Riga Technical University. At the time this was the first attempt to take such a voluntary step to introduce real environmental protection measures. As opposed to the experience of other national higher educational institutions, the responsible parties for the implementation of the EMS and development of the appropriate manual were students rather than employees of the Institute (see Fig. 3).

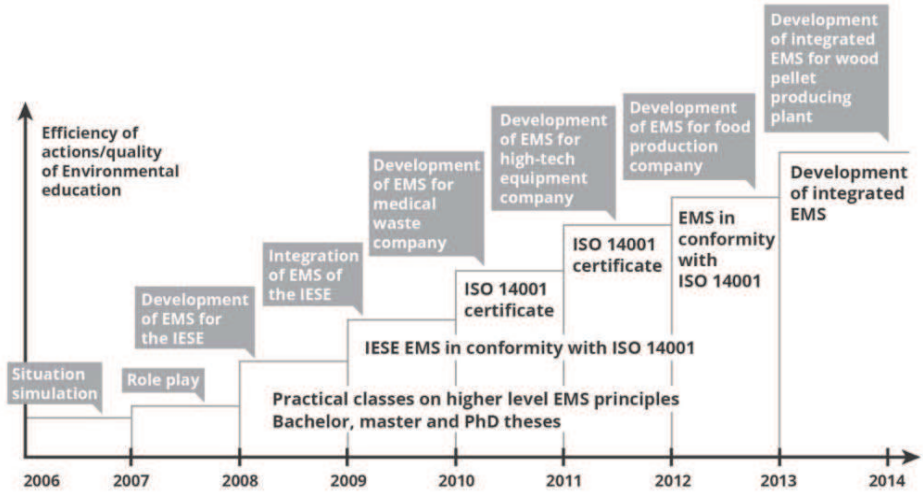

Figure 3. Progress of introduction of the CPBL teaching method in the study course Environmental Management Systems.

The efficiency of actions and the quality of the environmental education provided is assessed through a combination of: (a) anonymous student evaluations on the course completed annually which include questions on the relevance to the course to improvement of their skills and knowledge, the efficiency of the course in achieving its objectives, the quality of the lecturers and their performance; (b) performance of students in exams and practical exercises; (c) peer review of results through internal audit of the main result of the course; (d) degree of changes implemented in the

student-developed ISO 14001 programme by the target beneficiary (company) before certification.

As an institution that deals with environmental training of specialists, the main motivation for the introduction of the EMS in IESE was the interest of its staff and students to see how such a system: can impact educational processes and outcomes and create a positive image of the Institute among other environmental education organizations and higher education institutions, thus contributing to the sustainable development of Latvia as a whole. The results of the internal audit and management review conducted by the students showed that the established environmental management system and its implementation was in conformity with ISO 14001 standard requirements.

The introduction of the EMS in the Institute made several improvements in regard to environmental issues at the Institute:

- Sorting and recycling of used paper and cardboard was organised;
- Complete replacement of incandescent light bulbs with energy-saving lightings in two rooms;
- Arrangements made for the collection of used printer/copier cartridges;
- Instructions placed in the office and study rooms of the Institute with information on how to increase efficiency in use of lightening, electrical equipment and heating systems;
- Optimization of the Institute's documentation and procedures;
- Student surveys were introduced to improve the quality of studies.

As a result of the prioritization of environmental aspects, the quality of studies at the Institute proved to be the most important, albeit indirect, environmental aspect among all – both direct and indirect aspects. Since the Institute is not a large organization then, in comparison, its water, energy and material consumption is a lot smaller than it could be in other types of organizations. Thus, it was analysed that the quality of the studies (and thus their ability to develop qualitative environmental professionals), although indirect, is the aspect of the Institute that leaves the largest impact on the environment. The knowledge and skills that the students acquire, the scientific studies and research that are conducted in the Institute are the 'products' that are responsible for positive changes in society in sustainable development.

During the time from the launch of the Environmental Management Programme in the Institute the following has been achieved in terms of environmental performance (i.e. reduced pressure on the environment):

- The Institute has lobbied to achieve changes in the University to allow for student course works to be submitted electronically and for it to be possible to make any paper submissions (documents, theses, course works) on double-sided printed pages (both previously not allowed in the University);
- Since the priority environmental aspect, albeit indirect, was identified as the students themselves, then the increase of number of graduates in policy-level and decision-making positions in the Ministry of Environmental Protection and Regional Development, national agencies dealing with environmental monitoring, and others are considered to be testimony of improved performance;

- An annual open course on environmental issues was developed in 2008 and has steady increase (from 48 in the first year to almost 200 in 2014) of participants from the ministries of environment, agriculture and economy and other state institutions responsible for environment issues in Latvia, as well as environmental consultancy companies and other sector professionals. This shows an increase in the interest of specific knowledge and skills in decision-making on these pertinent issues in Latvia and the role of the Institute.

The main conclusions drawn during the implementation of the Institute's EMS were as follows:

- A good environmental management system in a higher educational establishment facilitates improving the attitudes of students, teachers and other employees towards the environment. Therefore, despite the fact that each individual is responsible for his/her own behaviour and its impact, the shared environmental performance improved significantly.
- It is important to include every person in the organization in the EMS implementation process, not only those who are directly responsible for environmental issues within the organisation. Experience shows that students are very happy to educate their professors in issues on how to maintain the EMS that they've created. Such information exchange between the students and the faculty members is organised in special meetings and within the annual internal audit process.
- The creation of an EMS in a higher education establishment where there is no environmental specialist training would require more time due to additional training that would be needed for the students and employees, since they would not have previous knowledge on environment issues.

2nd phase: The teaching methodology of the environmental management course in the Riga Technical University Institute of Energy System and Environment Institute is continually improved since 2006 (see Fig. 2). The goal of this teaching method is to provide an integrated platform for both theoretical knowledge and developing practical skills set on the establishment and maintenance of environmental management systems on all levels in various spheres. This process begins with a simple organization level – the students' own Institute and individual existing industrial companies. When the theory and practical skills in building an EMS are developed, the students can grasp better the contexts and complexities of environmental management that are present on the country level, on the regional level (among EU countries) and in the international fora (on issues related to international conventions and the management of such globally).

The experience from working with the students and employees from various companies in different sector has led the *Environmental Management Systems* course lecturers to conclude that is not possible to learn how to create, audit and maintain an environmental management systems without practical experience. Students in most cases have little understanding before the course begins about the real situation in companies – the financial difficulties they face, the organizational and technical obstacles prevalent in each company, resistance to change from employees and

sometime even a negative attitude against introducing environmental management systems. Student surveys conducted prior to the adaptation of the course indicated that students viewed this course as dull. Even theoretical tests and regular course work did not produce good results. Thus, year after year, the teaching methods have been advanced (see Fig. 2) in response to positive feedback from students in the previous year, and the introduction of each new method produced even better results (both from the viewpoint of the engagement of students and the quality of their work, and from the viewpoint of the students themselves through improved feedback on the course's popularity).

The skills of the students' are built through various steps in the practical work which are related in the points below.

1. The first trial was the **simulation** of an actual situation. Students are divided in small groups, and in parallel with lectures, are asked to develop a specific element of an environmental management system (policy, procedure, plan, etc.). These are prepared in line with a brief description of a fictional company prepared by the lecturer.

2. The more detailed view of the complexities of creating and implementing an EMS were provided through a role play. Each student throughout the semester filled the role of a specific person in a company by organizing meetings, resolving issues, making relevant decisions and preparing the necessary documentation. This allowed students to gain experience on group work and a deeper understanding of environmental aspects, their prioritization and the development of appropriate actions to deter the increase of any negative environmental impacts.

3. Another layer of experience is gained through the development and audit of the Institute's own environmental management system. Although this system has not been certified, each year the students are given the opportunity to audit the system and to check its progress through a documentation audit.

4. The best results are reached from the development of an environmental management system for an existing enterprise. In the past years, under the direction of their lecturers, the Institute's master's students have prepared EMS for four different industrial sector companies. These are a hazardous medical waste management company, a high-tech equipment manufacturer, a food manufacturing company and most recently – a wood pellet producing plant. The first two companies have already received their ISO 14001:2004 certification, which testifies that the systems developed by the students are conformity with all relevant international requirements. The last (wood pellet production company) involved the development of an environmental management system within an integrated system (ISO 14001 + ISO 9001 + OHSAS 18001).

The 3rd phase of the course is the application of the concepts which the students have acquired on environmental management systems and their individual elements (roles and responsibilities, programmes, prioritization, reporting and monitoring, etc.) from the organizational (company) level to higher, much more complex and larger-scaled hierarchical structures in environmental management on the systemic level – the country-level (primarily Latvia), the regional level (the European Union) and the global level. Through this exercise, the students conduct a **comparative analysis** of the elements of environmental management which can be identified at the various levels.

Through this, and a specific **gap assessment**, the students formulate the issues which are problematic and present challenges for countries, the EU and the global environmental conventions for ensuring proper management of environmental issues at each level.

CONCLUSIONS

A CPBL teaching method used in Environmental Science programme within a study course on Environmental Management Systems is presented in the Paper. The described educational programme and teaching methodology achieves its desired goal – increase in the level of specialists entering the workplace with improved skills on environmental management in:

- National environmental institutions,
- Local government institutions,
- Industrial and service sector companies,
- Project and planning offices,
- Educational establishments at all levels,
- International projects on environmental and clean technologies.

Since the students each year are required to become familiar with a specific company, they receive the skills on how to research and identify environmental aspects directly at their possible source and origin – with minimal access to documentation and one short site visit at their disposal for exploratory work. This develops skill in conducting rapid assessments, and the fact that the works is conducted with real company representatives means that the options for improvements in the company's system have to be realistic, implementable and economically sound in the existing market.

Due to the framework of the ISO 14001 standard and its logical approach Plan-Do-Check-Act, regardless of what position students will take in the future, they have a clear understanding of the cycle of planning and the importance of evaluating one's results and feeding lessons learned from the evaluation back into improving further processes.

The challenges and complexities in managing environmental issues on a broader scale (on the country, regional or global level) are hard concepts to grasp. The conflicting and competing interests (socio-economic, environmental, agricultural, health), resource constraints and political issues are difficult for students to grasp and challenging for educators to illustrate. By experiencing first-hand the difficulties in assessing environmental aspects, resolving conflicting interests, prioritizing actions, etc. on a much smaller scale (company-level), the students gain perspective on how these complexities may be magnified. As the number of actors, the geographical area, the scale of environmental issues, resource capacities and other issues increase on the national, regional and global level, the students draw conclusions on the gaps in environmental management at each level which prevent certain improvements and advancements in policy and actions.

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