SUSTAINABLE DEVELOPMENT IN ENGINEERING EDUCATION: A PEDAGOGICAL APPROACH

Andreas Ahrens[a] and Jelena Zaščerinska[b]
[a]*Department of Electrical Engineering and Computer Science, Faculty of Engineering, Hochschule Wismar, University of Technology, Business and Design, Wismar, Germany*
[b]*Centre for Education and Innovation Research, Riga, Latvia*

Abstract
Engineering education is facing a challenge of the development of student engineers' social responsibility in the context of sustainable development. The aim of the research is to analyze efficiency of engineering curriculum in the context of sustainable development underpinning elaboration of pedagogical guidelines on the development of students' social responsibility in engineering education. The analysis involves a process of analyzing the meaning of the key concepts sustainable development and engineering curriculum. Moreover, the study demonstrates how the key concepts are related to the idea of efficiency. The qualitative evaluation research has been used. The present empirical research was conducted during the Baltic Summer School „Technical Informatics and Information Technology" in 2009, 2010 and 2011. The sample involved 85 participants. The students' needs in Enterprise 2.0 were a criterion of efficiency of engineering curriculum in the context of sustainable development. Descriptive statistics was implemented for primary data analysis. The findings of the research allow drawing conclusions on efficiency of engineering curriculum for the development of students' social responsibility in the context of sustainable development. Pedagogical guidelines are elaborated.
KEYWORDS: Engineering Education, Sustainable Development, Teaching, Peer-Learning, Learning.

1. Introduction

Engineers were once able to initiate engineering projects, able to transform real needs into design and, finally, material form (Taoussanidis, 2010, p. 429). However, the social responsibility of engineers has become topical and places high demands on engineering education in the context of sustainable development. Higher education bears a significant responsibility for sustainability by virtue of its influence on society and academic freedom to explore ideas (Davies, Edmister, Sullivan, West, 2003). That is why engineering education has attracted a lot of research efforts on the development of student engineers' social responsibility in the context of sustainable development (Allenby, Folsom Murphy, Allen, Davidson, 2009). The research demonstrates the shift in engineering education from the conventional engineering curriculum limited to techno-economic issues (Taoussanidis, 2010, p. 429) to the curriculum centred on economic, social and environmental dimensions of life, thereby developing student engineers' social responsibility.

The remaining part of this paper is structured as follows: The aim of the present contribution is determined in Section 2. Section 3 demonstrates the object of the present research. Methods and methodologies of the present research are shown in Section 4. Section 5 presents theoretical framework of the pedagogical approach in engineering education for sustainable development and analysis of the empirical study. Afterwards, conclusions on efficiency of engineering curriculum for the development of student engineers' social responsibility in the context of sustainable development and pedagogical guidelines on the development of student engineers' social responsibility in engineering education are given in Section 6. Finally, some concluding remarks and a short outlook on interesting topics for further work are elaborated.

2. Aim of the research

The aim of the research is to analyze efficiency of engineering curriculum in the context of sustainable development underpinning elaboration of pedagogical guidelines on the development of student engineers' social responsibility in engineering education.

3. Object of the research

The object of the research is development of student engineers' social responsibility in engineering curriculum in the context of sustainable development.

4. Methods and Methodologies

The method of the present research involves a process of analyzing the meaning of the key concepts *sustainable development* and *engineering curriculum*. Moreover, the research demonstrates how the key concepts are related to the idea of *efficiency*. The study presents how the steps of the process are related and shows a potential model for development: sustainable development → sustainable development in education → engineering curriculum design in the context of sustainable development → modelling Enterpise 2.0 application in engineering curriculum in the context of sustainable development → empirical study within a multicultural environment.

The methodological background of the present research is based on System-Constructivist Theory introduced as New or Social Constructivism Pedagogical Theory.

It should be mentioned that the Activity Theory by Leontyev (Leont'ev, 1978, p. 7) made a distinction between the individual's *action*, and the social *activity* of which it is a part (Leont'ev, 1978, p. 7) and which gives it meaning (Blunden, 2009, p. 10). Although Activity Theory is associated with the name of Leontyev rather than Vygostky, the *activity* concept originated with Vygotsky (Blunden, 2009, p. 10). System-Constructivist Theory and, consequently, System-Constructivist Approach to learning introduced by Reich (Reich, 2005) emphasize that human being's point of view depends on the subjective aspect:

- everyone has his/her own system of external and internal perspectives that is a complex open system and
- experience plays the central role in the knowledge construction process (Maslo, 2007, p. 39).

The methodology based on the methodological background of the present research is identified as development of the system of external and internal perspectives. Therein, the term *perspective* in the present research means to embody certain fundamental assumptions (Barry, 2002, p. 3). The initial components of the development of the system of external and internal perspectives based on findings of Vygotsky (Vygotsky, 1934/1962) and Robbins (Robbins, 2007, p. 49-54) are depicted in Figure 1.

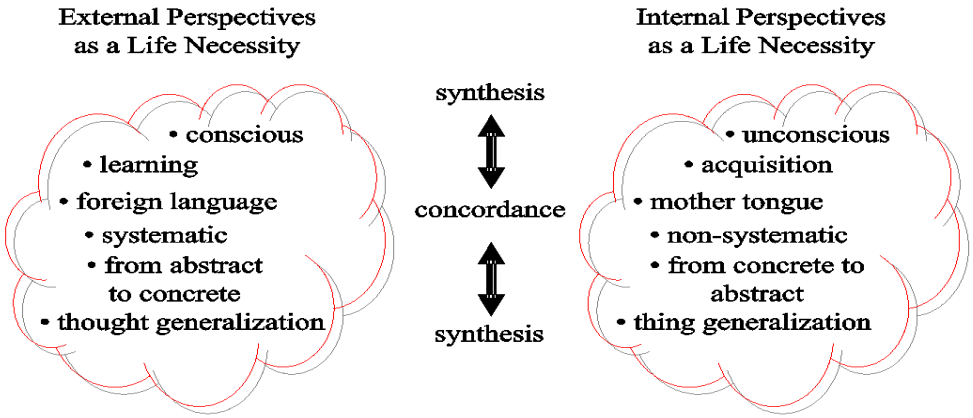

Figure 1: Development of the system of external and internal perspectives

The social level (the external perspective) accentuates social interaction of development (Surikova 2007, p. 384). Therein, social interaction is defined as the unity of outside developmental circumstances and individual psychological characteristics in his/her experience (Surikova, 2007, p. 384). The individual level (the internal perspective) focuses on cognitive activity (Surikova 2007, p. 384). Cognitive activity refers to the unity of processes of sense, perception, attention, memory, thinking, speech and imagination, by which people perceive, remember, think, speak, and solve problems. In other words, any function in the individual cultural development appears at the beginning between people (as interpsychical or intermental category), and then – on the intrinsic level (as intrapsychical or intramental category) (Wells, 1994, p. 3). As the process, the methodology of the development of the system of external and internal perspectives has its cyclic nature. The development of the system of external and internal perspectives is based on Law of Development or interiorization (Vygotsky, 1934/1962) formulated by Vygotsky as transformation of the external culture into the individual internal (Wells, 1994, p. 3) that means that any function in the individual cultural development appears twice or on two planes (Wells, 1994, p. 3): first on the social level (the external perspective) and later, on the individual level (the internal perspective). Hence, the phase of unity of external and internal perspectives (the system of interacting phenomena) is determined as the sub-phase between the social level (the external perspective) and the individual level

(the internal perspective) as shown in Figure 2. The phases of interiorization determine the essence of the methodology of the development of the system of external and internal perspectives and its implementation's sequence from the external perspective to the internal perspective through the phase of unity of external and internal perspectives (the system of interacting phenomena) as demonstrated in Figure 2.

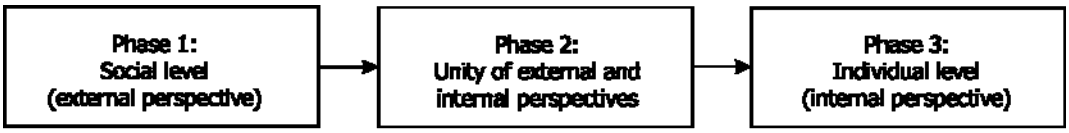

Figure 2: Phases of interiorization

Moreover, complemented components of external and internal perspectives are identified in Table 1 based on the analysis of the external culture and the individual internal culture within Law of Development or interiorization (Vygotsky, 1934/1962).

Table 1: **Complemented components of external and internal perspectives**

External Perspective	Development of the system	Internal Perspective
- meaning - denotation - scientific - whole	- schemas - chunks - gambits - concept system - grammar - new type of function	- sense - personal meaning - spontaneous - part - connotation

Moreover, the authors' position on the present research based on the methodology of the development of the system of external and internal perspectives is reflected in principles of mutual sustainability and mutual complementarity. The principle of mutual sustainability means to provide a complex of possibilities to learn for everyone (both student and educator in the present research), and reflected principle of complementarity reveals that the opposite things (principles in the present research) supplement each other for finding the truth.

5. Results of the Research

5.1. Theoretical Framework on Sustainable Development in Engineering Education

Sustainable development is defined as development that meets the needs of the present generation without compromising the chances of future generations to meet their own needs and aspirations (United Nations General Assembly, 1987). Sustainable development aims to achieve three types of approaches to solving the three categories of objectives: economic, social, environmental as shown in Figure 3.

Figure 3: Dimensions of sustainable development

Thus, sustainable personality is “a person who sees relationships and inter-relationships between nature, society and the economy” (Rohweder, 2007, p. 24). In other words, this is a person who is able to develop the system of external and internal perspectives as demonstrated in Figure 1, and in turn the system of external and internal perspectives becomes a main condition for the sustainable personality to develop. Sustainable development in engineering education is about giving engineers an understanding of the issues involved as well as about raising their awareness of how to work and act sustainably (Taoussanidis, 2010, p. 430). The resulting concept is that “the engineer should be a first-rate technical expert who acts as a social agent, rather than just a technician” (Clift, 1998, p. 155) with a “broad understanding of the social and philosophical context in which he will work” (Perdan, Azapagic, Clift, 2000, p. 170). In engineering education curriculum is a central, organizing stance (Portelli, Vilbert, 2002a, p. 39). The search for engineering curriculum in the context of sustainable development reveals the complexity in terms of scientific and theoretical fundamentals, prevailing concepts as well as current practical applications. Moreover, the interaction of synonyms of the term *curriculum*, namely, *approach, plan* (often in Germany and Russia), *design*, *way of thinking* as well as *strategy* and *programme* has been found. Curriculum comprises the following components: aim, objectives, content, process of teaching and learning as well as evaluation as depicted in Figure 4.

Curriculum based on System-Constructivist Approach to learning centres on the possibilities for the co-construction and co-production of innovation, thereby developing student engineers' social responsibility, rather than on innovation as simply educator transmitted or simply engineering student created (Portelli, Vilbert, 2002a, p. 39). Therein, curriculum is centred on the process design (Philippou, 2005, p. 357).

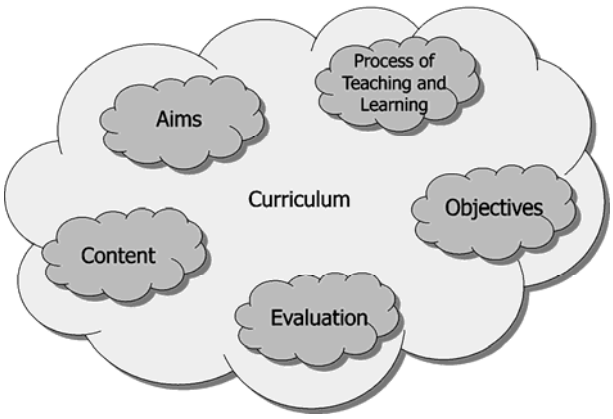

Figure 4: Curriculum components

The methodology of the development of the system of external and internal perspectives determines the implementation of the curriculum process to proceed in three following phases: from the external perspective or teaching to the internal perspective or learning through the phase of the unity of external and internal perspectives and/or the system of interacting phenomena or peer-learning as shown in Figure 5.

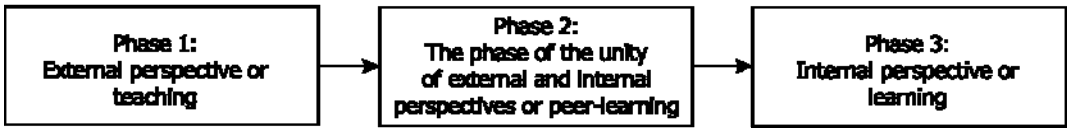

Figure 5: Inter-connections between the methodology of the development of the system of external and internal perspectives and curriculum process

Moreover, the paradigm changes from an input based teaching/learning process to an outcome based process (Bluma, 2008, p. 673), thereby developing student engineers' social responsibility. Hence, the curriculum demonstrates how the learning outcomes are to be achieved by determining the phases of the process of teaching and learning: the process of teaching and learning gradually proceeds from teaching in Phase 1 to learning in Phase 3 through peer-learning in Phase 2 as depicted in Figure 6.

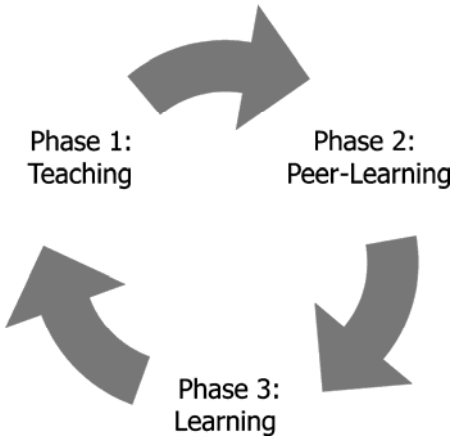

Figure 6: Phases of the process of teaching and learning

The stages of curriculum design involve needs analysis, aims and objectives of the course, approaches and principles, syllabus design or the course content (Lūka, 2008, p. 4), content/sequencing/organization, materials and support, methods as well as evaluation and assessment. In its turn, engineering curriculum design in the context of sustainable development includes the following steps (Boev, Kriushova, Kulyukina, Surygin, Freeston, Heitmann, Chuchalin, 2011, p. 41-42):

- Step 1: Curriculum conception (a brief description of the curriculum) that is aimed at identifying the curriculum constituencies defined as stakeholders (Boev, 2011) and creation of the system ensuring the interaction with constituencies and studying of their needs.
- Step 2: Determination of curriculum educational objectives that are based on the needs of the constituencies. The curriculum objectives should be consistent with the mission of the institution to ensure its market competitiveness and demand of constituencies.
- Step 3: Definition of measurable curriculum learning outcomes, namely, knowledge, skills and attitudes, which a student acquires during his study within the curriculum. The curriculum learning outcomes should correspond with the needs of the constituencies and ensure the achievement of the programme objectives by the graduates.
- Step 4: The curriculum design that demonstrates how the learning outcomes are to be achieved by defining the curriculum modules that ensure their achievement and by assigning European Credit Transfer and Accumulation System (ECTS) to learning outcomes. Each module has a number of learning outcomes that have their credit value depending on their contribution to achievement of programme outcomes. An educator responsible for a module must ensure development of its syllabus, teaching technologies, and supporting facilities aiming at achievement of module learning outcomes. Each module must have the assessment methods and tools for achievement of planned learning outcomes. The credits should not be assigned to a module if module does not include assessment of outcomes to be achieved. The notional learning time for a module is defined in accordance with its credit value.
- Step 5: Development of the assessment system for achievement of learning outcomes and curriculum objectives that should be done systematically and used for curriculum continuous improvement. The professional accreditation of curriculum by the accrediting agency is an important part of the assessment system of an institution.

5.2. Empirical Research

The design of the present empirical research comprises the purpose and question of the present empirical study, sample of the present empirical study and methodology of the present empirical study. The present empirical study was conducted during student engineers' Enterprise 2.0 application in the engineering curriculum of Baltic Summer School *Technical Informatics and Information Technology* to examine efficiency of Enterprise 2.0 application in engineering curriculum. Its topicality is determined by ever-increasing flow of information and business processes in which an important role is laid to Enterprise 2.0 as a means of getting information and gaining experience. The research question is as follows: Has student engineers' Enterprise 2.0 application been efficient? The present research conducted

during the Baltic Summer School „Technical Informatics and Information Technology" in 2009, 2010 and 2011 involves 85 respondents, namely,

- 22 participants of Fifth Baltic Summer School *Technical Informatics and Information Technology* at the Institute of Computer Science of Tartu University, August 7-22, 2009, Tartu, Estonia, for the case analysis,
- 28 participants of Sixth Baltic Summer School *Technical Informatics and Information Technology* at Kaunas Technical University, August 13-28, 2010, Kaunas, Lithuania, for the case analysis,
- 24 participants of Seventh Baltic Summer School *Technical Informatics and Information Technology* at Riga Technical University, August 12-27, 2011, Riga, Latvia, for the case analysis,
- an educator of Baltic Summer School *Technical Informatics and Information Technology* for the internal evaluation and
- 10 researchers in the field of educational research from different countries for the external evaluation.

All the participants of Baltic Summer School *Technical Informatics and Information Technology* have got Bachelor or Master Degree in different fields of Computer Sciences and working experience in different fields related to computing and information technology. The participants of Baltic Summer School *Technical Informatics and Information Technology* are with different cultural background and diverse educational approaches from different countries, namely, Latvia, Lithuania, Estonia, Russia, Belarus, Mongolia, Egypt, Germany, Pakistan, Indonesia, Great Britain, China, India, Nigeria, Romania and Mexico, etc. Hence, the sample is multicultural as the respondents with different cultural backgrounds and diverse educational approaches were chosen. That emphasizes the study of individual contribution to the development of student engineers' Enterprise 2.0 application (Lūka, Ludborza, Maslo, 2009, p. 5). It should be also mentioned that whereas cultural similarity aids mutual understanding between people (Leontiev quoted by Robbins, 2007, p. 55), the students' different cultural and educational backgrounds contribute to successful learning and become an instrument of bringing the students together more closely under certain conditions, namely, appropriate materials, teaching/learning methods and forms, motivation and friendly positioning of the educator (Abasheva, 2010, p. 431). Hence, the group's socio-cultural context (age, field of study and work, mother tongue, etc.) is heterogeneous.

Interpretative research paradigm which corresponds to the nature of humanistic pedagogy (Lūka, 2008, p. 52) has been determined. Interpretative paradigm is characterized by the researchers' practical interest in the research question (Cohen, Manion et.al., 2003). Checking the efficiency of pedagogic interventions and organizational changes in complex and constantly self-regenerating environments (Kardoff, 2004, p. 137) employs the qualitative evaluation research (Flick, 2004, p. 149). Hence, the qualitative evaluation research aimed at examining efficiency of Enterprise 2.0 application has been used in the study. Therein, efficiency involves quality and effectiveness as depicted in Figure 7.

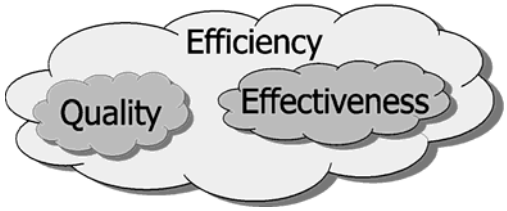

Figure 7: Elements of efficiency

Quality of Enterpise 2.0 application is regarded as the improvement of student engineers' knowledge, skills and attitudes. In its turn, effectiveness is considered as the educator's contribution to the student engineers' knowledge, skills and attitudes in Enterpise 2.0 application.

Enterpise 2.0 application is efficient if the inputs (Enterpise 2.0 application) produce the maximum output (students' knowledge, skills and attitudes (European Commission, 2006, p. 2). Therein, students' knowledge, skills and attitudes is the outcome criterion of efficiency of Enterpise 2.0 application. Figure 8 shows how the qualitative evaluation research proceeds from the phase of exploration of the context analysis aimed at determining the present situation of Enterpise 2.0 application in promoting students' motivation and their readiness to implement the joint activity, through the description of the practice that analyzes differences in levels of features researched and to the phase of generalization of the model that evaluates efficiency of Enterpise 2.0 application for the development of students' knowledge, skills and attitudes.

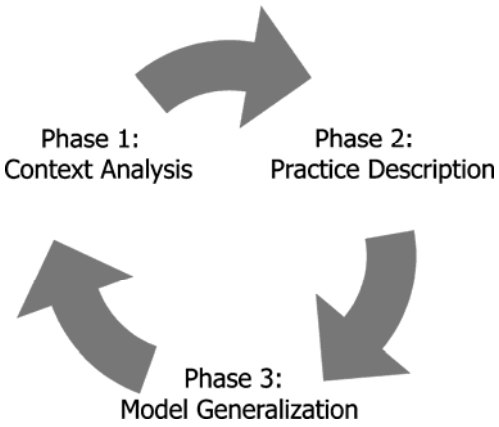

Figure 8: Phases of the qualitative evaluation research

The qualitatively oriented research allows the construction of only few cases (Mayring, 2007, p. 1). Moreover, the cases themselves are not of interest, only the conclusions and transfers we can draw from this material (Mayring, 2007, p. 6). Selecting the cases for the case study comprises use of information-oriented sampling, as opposed to random sampling (Flyvbjerg, 2006, p. 229). This is because an average case is often not the richest in information. In addition, it is often more important to clarify the deeper causes behind a given problem and its consequences than to describe the symptoms of the problem and how frequently they occur (Flyvbjerg, 2006, p. 229). Random samples emphasizing representativeness will seldom be able to produce this kind of insight; it is more appropriate to select some few cases chosen for their validity.

The present part of the empirical study reveals analysis of engineering students' learning outcomes in Enterprise 2.0 application within Baltic Summer School *Technical Informatics and Information Technology* in 2009, 2010 and 2011 through thorough analysis of two surveys of the student engineers' feedback regarding their needs before and after educators' contribution.

Baltic Summer School *Technical Informatics and Information Technology* takes part in the Baltic States since 2005. The International Summer School offers special courses to support the internationalization of education and the cooperation among the universities of the Baltic Sea Region. The goal of studies in Baltic Summer School *Technical Informatics and Information Technology* is to prepare the student for international Master and Ph.D. programs in Germany, further specialization in computer science and information technology or other related fields, and learning in a simulated environment. Baltic Summer School *Technical Informatics and Information Technology* contains a special module on Web 2.0 where Enterprise 2.0 is part. The present research is based on a widely accepted conception of Enterprise 2.0 as use of Web technologies for enterprise (business) purposes. Typical Enterprise 2.0 of Web 2.0 techniques and technologies include corporate blogs, wikis, feeds and podcasts (Vossen, 2009, p. 38) as shown in Figure 10.

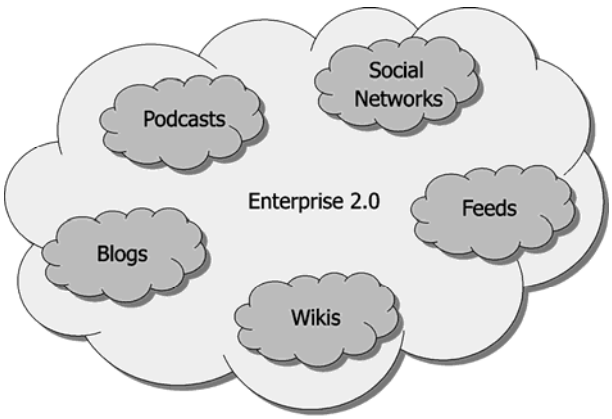

Figure 10: Elements of Enterprise 2.0

In 2009 analysis of the students' feedback regarding their needs in Enterprise 2.0 application in the pre—and post-survey was based on the following questionnaire:

- Question 1: Do you know the word *Web 2.0*?
- Question 2: Do you know the basic idea of Web 2.0?
- Question 3: Have you already used Web 2.0, namely, Facebook, Twitter, Wikipedia, etc?
- Question 4: Do you think Web 2.0 requires a lot of profound knowledge, namely, math, physics, etc?
- Question 5: Do you think Web 2.0 is useful for your individual needs?
- Question 6: Do you think Web 2.0 is useful for your organizational use?
- Question 7: Do you think Web 2.0 is useful for your professional use?

It should be mentioned that needs analysis of three levels - individual, organizational and professional - serves as a basis for designing a questionnaire (Surikova, 2007, p. 389). By individual purposes private use of Enterprise 2.0 is meant: business functions are used within the family and friends. By organizational purposes use of Enterprise 2.0 between the colleagues is determined: business is made between the participants within the enterprise. And by professional purposes Enterprise 2.0 is used for business with the partners of the enterprise.

Students' experience - knowledge, skills and attitudes - is an indicator of Enterprise 2.0 application in engineering education.

The evaluation scale of five levels for each question is given where "1" means "disagree" and low level of experience in Enterprise 2.0 application and "5" points out "agree" and high level of experience in Enterprise 2.0 application. Analysis of the pre-survey, as depicted in Figure 9, carried out with 22 participants of Fifth Baltic Summer School, shows that the student engineers' Enterprise 2.0 application is heterogeneous as well as the student engineers don't know the possibilities offered by Web 2.0 properly.

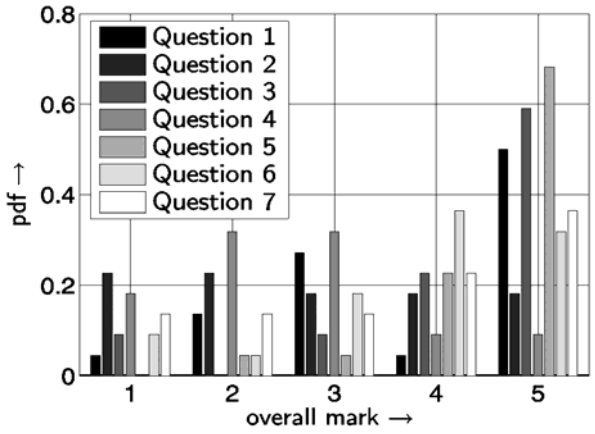

Figure 9: PDF (probability density function) of the pre-survey on August 7, 2009

In 2010 analysis of the students' feedback regarding their needs in Enterprise 2.0 application in the pre—and post-survey was based on the following questionnaire:

- Question 1: Do you know the concept of Enterprise 2.0?
- Question 2: Do you use Enterprise 2.0 for your individual purposes?
- Question 3: Do you use Enterprise 3.0 for your organizational purposes?
- Question 4: Do you use Enterprise 3.0 for your professional purposes?
- Question 5: Do you participate in activities for your professional development - education, in-service training and/or learning - in use of Enterprise 3.0?

The evaluation scale of five levels for each question is given where "1" means "disagree" and low level of experience in Enterprise 2.0 application and "5" points out "agree" and high level of use of Enterprise 2.0 technologies. Results of the pre-survey of needs in Enterprise 2.0 application reveal that the student engineers do not realize the possibilities offered by Enterprise 2.0 properly.

In 2011 analysis of the students' feedback regarding their needs in Enterprise 2.0 application in the pre—and post-survey was based on the following questionnaire:

- Question 1: Do you have your own business and / or enterprise? The evaluation scale of two levels for the question is given where "1" means "no" and "2" - "yes".

- Question 2: Do you plan to start your own business and / or enterprise? The evaluation scale of two levels for the question is given where "1" means "no" and "2" - "yes".
- Question 3: To which extent do modern business and enterprise employ Web technologies? The evaluation scale of five levels for the question is given where "0-20%" means a low level of experience in Enterprise 2.0 application and "80-100%" points out a high level of Enterprise 2.0 application.
- Question 4: Please, indicate at least 3 Web technologies used by business and / or enterprise for business applications. The evaluation scale of three levels for the question is given where "1" means a low level of experience in Enterprise 2.0 application and "3" points out a high level of Enterprise 2.0 application.

Results of the pre-survey of needs in Enterprise 2.0 application reveal that the student engineers do not realize the possibilities for business offered by Enterprise 2.0 properly: one engineering student has got his/her own business, 11 engineering students plan to start their own business and / or enterprise, nine engineering students consider that modern business employs Web technologies to 40-60%, 10 student engineers – 60-80% and five engineering students – 80-100%. Six student engineers indicated one Web technology used by business, three engineering student - two Web technologies used by business, 14 student engineers – three Web technologies used by business and one engineering student – five Web technologies used by business.

This is a reason why a support system to contribute to students' learning outcomes in a multicultural study's context was elaborated. This support system differs from the one offered in the special module of Web 2.0 by other educators as the proposed support system proceeds in a certain sequence.

Theoretical analysis and empirical findings of the research contribute to the model of Enterprise 2.0 application in engineering curriculum implemented within Baltic Summer School *Technical Informatics and Information Technology* as following:

- Enterprise 2.0 application in engineering curriculum is conceptualized as promoting student engineers' self-confidence and capability to cope with their own problems in all spheres of life in a knowledgeable and enterprising way, fostering students' enterprise capability (Oganisjana, Koke, 2008, p. 225).
- Educational objective of Enterprise 2.0 application in engineering curriculum is determined as to actively involve the student engineers as prospective employees in the life of Enterprise 2.0 (Portelli, Vilbert, 2002b, p. 15) by providing innovative opportunities and organizing student engineers' cognitive activity.
- Measurable learning outcomes are defined as
    - student engineers' knowledge of the Enterprise 2.0 concept,
    - student engineers' skills to use Enterprise 2.0 for their individual, organizational and professional purposes,
    - student engineers' attitude towards participation in activities for their professional development - education, in-service training and learning.
- Enterprise 2.0 application is implemented in the Web 2.0 module of engineering curriculum. The Web 2.0 module examines the advantages and problems of this technology, namely, architecture and management, protocol design, and programming, which makes new social communication forms possible. The Web 2.0 module does not reveal the concept of Enterprise 2.0. However, the Web 2.0 module comprises Enterprise 2.0 technologies. The Web 2.0 module is assigned to 1 credit relevant to the European Credit Transfer System (ECTS). The teaching technology proceeds as following:
    - Phase 1: *Teaching* in Enterprise 2.0 application is aimed at a safe environment for all the students considering the essence of constructive social interaction and its organizational regulation. The present phase of Enterprise 2.0 application is organized in a frontal way involving the students to participate.
    - Phase 2: *Peer-Learning* in Enterprise 2.0 application is designed for the students' analysis of an open professional problem situation and their search for a solution. The present phase of Enterprise 2.0 application involves the students to act in peers. A variety of teaching/learning techniques and/or activities with use of Enterprise 2.0 is provided by role plays, simulations, dialogues, prepared talks, discussions, and communication games and information-gap activities.

- Phase 3: *Learning* in Enterprise 2.0 application emphasizes the students' self-regulation with use of assessment of the process and self-evaluation of the results. The students present their self-evaluation by the end of each class.

- The assessment system for achievement of learning outcomes and curriculum objectives comprises student engineers' self-evaluation, internal evaluation and external evaluation (Hahele, 2005).

In 2009 analysis of the post-survey carried out in Fifth Baltic Summer School *Technical Informatics and Information Technology* on August 11, 2009 reveals that the participants' learning outcomes has become homogeneous, and the participants have put the emphasis on Enterprise 2.0 application for professional needs as shown in Figure 11.

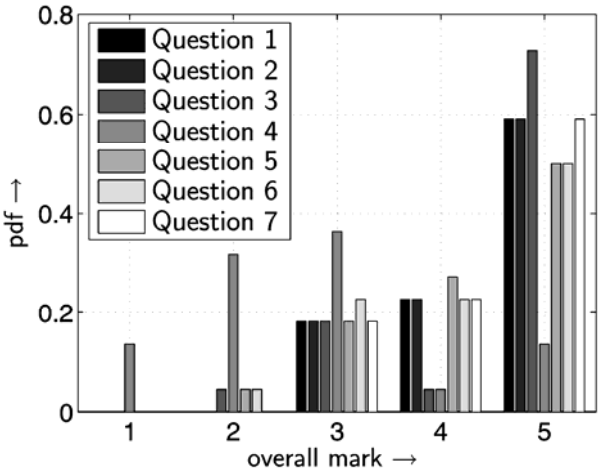

Figure 11: PDF (probability density function) of the post-survey on August 11, 2009

In 2010, after having applied Enterprise 2.0 in the Web 2.0 module, results of the post-survey demonstrate the positive changes in comparison with the pre-survey:

- the level of the participants' experience in terms of knowledge of the concept of Enterprise 2.0 has been enriched,
- the level of the participants' experience in Enterprise 2.0 application for individual needs, for organizational and professional needs increased and
- the level of the participants' experience in terms of participation in activities for professional development, namely, education, in-service training and/or learning, has been improved.

In 2011 after having applied Enterprise 2.0 in the Web 2.0 module, results of the post-survey demonstrate the positive changes in comparison with the pre-survey:

- The number of engineering students who plan to start their own business increased from 11 to 16.
- The number of student engineers who considered that modern business employs Web technologies to 40-60% decreased from nine to five, 60-80% - decreased from 10 to nine and 80-100% - increased from five to 10 engineering students.
- The number of engineering students who indicated one Web technology used by business decreased from six student engineers to 5, two Web technologies used by business – decreased from three engineering student to one, three Web technologies used by business – increased from 14 student engineers to 15 and five Web technologies used by business – increased from one engineering student to three.
- The number of students who has got his/her own business remained steady – one engineering student.

The present part reveals analysis of the research results in Enterprise 2.0 application within Baltic Summer School *Technical Informatics and Information Technology* in 2009, 2010 and 2011 through thorough analysis of student engineers' self-evaluation, internal evaluation and external evaluation. In order to find out how each student's learning outcomes changed after Enterprise 2.0 application in 2010, analysis of the engineering students' self-evaluation comprised the structured interviews of three questions:

- What is your attitude to the Enterprise 2.0 application?

- What have you learned in the Enterprise 2.0 application?
- How can you apply this knowledge in your academic field?

The aim of the interviews was to reveal the engineering students' evaluation of Enterprise 2.0 application for the development of student engineers' learning outcomes. Comparing the answers of those 24 engineering students in the sample, the structured interviews are focused on the engineering students' positive experience in Enterprise 2.0 application. For example**,** a student reveals the inter-relationship between the positive experience of social interaction and cognitive activity in Enterprise 2.0 application:

"I feel this class to be very useful to me because I am improving my knowledge in Enterprise 2.0 application".

The student evaluates his/her own learning process:

"I think I like the Web 2.0 module, because I have understood how to apply Enterprise 2.0".

Summarizing content analysis (Mayring, 2004, p. 269) of the structured interviews demonstrates that Enterprise 2.0 application in the context of sustainable development promote the development of students' learning outcomes. Moreover, Enterprise 2.0 application contributes to the safe and friendly teaching/learning environment for all the participants and provides opportunities of constructive social interaction and cognitive activity.

Internal evaluation involves internal evaluators, namely, engineering students and educators of the educational establishment (Hahele, 2005, p. 37). Analysis of internal evaluation of the engineering students' learning outcomes comprised the data processing, analysis, interpretation and analysis of the results of the pre-survey and post-survey of the student engineers. In order to determine the developmental dynamics of each student's learning outcome in **2010**, comparison of the pre-survey and post-survey results was carried out. The *Mean* results of the descriptive statistics highlighted in Table 2 demonstrate that the level of the students' learning outcomes has increased in the post-survey (3,28) in comparison with the pre-survey (1,68).

Table 2: **Mean analysis of the pre- and post-survey in 2010**

Question	Pre-Survey	Post-Survey
1	1,86	3,25
2	1,75	3,44
3	1,54	3,33
4	1,57	3,16
5	1,68	3,21
mean	1,68	3,28

The comparison of the *Standard Deviation* results as shown in Table 3 reveals that the scores of the post-survey are spread wider than the scores in the pre-survey.

Table 3: **Standard Deviation analysis of the pre- and post-surveys in 2010**

Question	Pre-Survey	Post-Survey
1	1,85	2,35
2	1,14	2,40
3	1,99	2,39
4	1,57	2,19
5	1,96	2,31
mean	1,70	2,33

The results of *Mean* and *Standard Deviation* within the surveys of the students' feedback regarding their needs in Enterprise 2.0 reveal that most of answers are concentrated around Level 2 and 3. Thus, there is a possibility to increase the students' Enterprise 2.0 application within Web 2.0 technologies.

In order to determine the developmental dynamics of each student's learning outcome **in 2011**, comparison of the pre-survey and post-survey results was carried out. The *Mean* results of the descriptive statistics highlighted in Table 4 demonstrate that the level of the students' learning outcomes has increased in the post-survey (2,39) in comparison with the pre-survey (2,15).

Table 4: **Mean analysis of the pre- and post-survey in 2011**

Question	Pre-Survey	Post-Survey
1	1, 04	1, 04
2	1, 46	1, 66
3	3, 83	4, 21
4	2, 25	2, 66
mean	2, 15	2, 39

The results of *Mean* within the surveys of the students' feedback regarding their needs in Enterprise 2.0 reveal that most of answers are concentrated around Level 2. Thus, there is a possibility to increase the students' use of Enterprise 2.0 within Web 2.0 technologies. Hence, considering judgment to be part of the art of statistics (Gigenzer, 2004, p. 603), the conclusion has been drawn that Enterprise 2.0 application in the context of sustainable development influenced the development of the engineering students' learning outcomes demonstrated by the difference between the levels of the student engineers' learning outcomes in the pre- and post-survey.

For the external evaluation the choice of experts was based on two criteria, namely, recognized knowledge in the research topic and absence of conflict of interests (Lopez, Salmeron, 2011, p. 202) as depicted in Figure 12.

Figure 12: Criteria of choosing experts for external evaluation

The number of experts depends on the heterogeneity of the expert group: the greater the heterogeneity of the group, the fewer the number of experts (Okoli, Pawlovski, 2004, p. 20). Thus, 10 is a good number of experts for the study (Lopez, Salmeron, 2011, p. 202). Therein, the external evaluation comprises 10 researchers from different countries. It should be mentioned that all the researchers participated in the external evaluation of the research results are professors in the fields connected with educational research. All the 10 researchers have decisively contributed to their fields of research. For example, the present research employs the finding of a researcher on the *quasi-concept.* Another investigates use of external and internal perspectives in empirical studies, namely, the external perspective means viewing the world from the researcher's or scientist's view and the internal perspective – from the subject's view. All the 10 researchers have got extensive research experience. Analysis of the external evaluation of the research

results comprised non-structured interviews of one question as following: What is the researcher's view on Enterprise 2.0 application for the development of engineering students' learning outcome? The aim of the non-structured interviews was to reveal the researchers' evaluation of Enterprise 2.0 application for the development of engineering students' learning outcome.

For example, a respondent considered the organization model of Enterprise 2.0 application for the development of engineering students' learning outcome to be a transformative methodology. The researcher stressed the following advantages of the present transformative methodology:

- focus of establishing a system,
- the fascinating idea of positioning the *quasi-concept* within the *quasi-autonomous zone*,
- viewing the overall personality of the learner,
- the fact that educators can indeed change the typical classroom environment,
- good point to connect the external with the internal,
- Vygotsky's Law of Development selected,
- the scheme titled *Organisation of Productive Professional Environment*, including both external and internal factors,
- the essence and sequence of the implementation of the organization model for tertiary teaching/learning,
- developing newer constructs that will truly help the student to internalize new material and
- the student having the "ability to create knowledge".

Summarizing content analysis (Mayring, 2004, p. 269) of the data reveals that the respondents evaluate Enterprise 2.0 application for the development of engineering students' learning outcome in the context of sustainable development positively. Thus, the conclusion can be drawn that Enterprise 2.0 application in the context of sustainable development enhances development of engineering students' learning outcome.

6. Conclusions and Directions for Further Studies

The findings of the research allow drawing conclusions on efficiency of engineering curriculum for the development of student engineers' learning outcomes as student engineers' social responsibility in the context of sustainable development. Regarding quality assurance, it is evident that the student engineers' learning outcomes have been enriched. The engineering students have gained their social experience for the development of their learning outcomes, and thus social experience changed into the means of gaining new opportunities and advantages. Irrespective of levels in the students' initial Enterprise 2.0 capacity, Enterprise 2.0 application has become an effective means of acquiring social experience by the engineering students in order to improve their learning outcomes. Enterprise 2.0 application resulted in the improved engineering students' learning outcomes. Therein, Enterprise 2.0 application has contributed to the development of the engineering students' learning outcomes. Regarding effectiveness of the educator's contribution to the student engineers' learning outcomes, it is evident that the engineering students widened their experience in social interaction and cognitive activity with Enterprise 2.0 application. The engineering students' social experience and attitude are positive. That shows that Enterprise 2.0 application in engineering curriculum influence the student engineers' learning outcomes. Moreover, validity of the qualitative evaluation research has been provided by use of the mixed methods' approach to the data obtaining, processing and analysis. Validity and reliability of the research results have been provided by involving other researchers into several stages of the conducted research. External validity has been revealed by international co-operation as following:

- the research preparation has included individual consultations given by the Western researchers,
- the present contribution has been worked out in co-operation with international colleagues and assessed by international colleagues, and
- the research has been presented at international conferences.

Therein, the researchers' positive evaluation of Enterprise 2.0 application for the development of engineering students' learning outcomes validates the findings of the present research.

Thus it might be stressed that Enterprise 2.0 application is efficient if it provides student's personal experience in social interaction as a condition for creation of new knowledge: if students' needs are met, and a support system - Enterprise 2.0 application - implemented in phases of a certain sequence is designed that would secure their social experience in social interaction and cognitive activity, engineering students demonstrate better results of the learning outcomes.

The present research has *limitations*. The inter-connections between engineering students' learning outcomes, Enterprise 2.0 application and the sequence of its implementation have been set. Another limitation is the empirical study conducted by involving educators and students of one tertiary institution. Therein, the results of the study cannot be representative for the whole area. Nevertheless, the results of the research - definition of Enterprise 2.0, Enterprise 2.0 application in engineering curriculum and the qualitative evaluation research - may be used as a basis of the development of engineering students' learning outcomes of other tertiary institutions. If the results of other tertiary institutions had been available for analysis, different results could have been attained. There is a possibility to continue the study.

The following pedagogical guidelines on Enterprise 2.0 application in engineering curricula are elaborated: Enterprise 2.0 application proceeds from Phase 1 *Teaching* aimed at determining the notion of constructive social interaction and its organizational regulation through Phase 2 *Peer-Learning* designed for the students' analysis of an open academic problem situation and their search for its solving that provide each student with the opportunity to construct his/her own social experience to Phase 3 *Learning* focused on the students' self-regulation with use of evaluation of the process and self-evaluation of the result.

One of the directions of further research is to consider the historical development of *Enterprise 2.0* and *Enterprise 2.0* in pedagogy. Table 5 demonstrates that the study of *Enterprise 3.0* and *Enterprise 3.0* in pedagogy has not had a long story.

Table 5: **Enterprise 2.0 in pedagogy in different historical periods**

Phase	Historical Period	Approach	Elements of Enterprise	Educational settings
1.	2000 - 2006	Enterprise 1.0 as socialization	Social software	Tasks with use of Enterprise 1.0
2.	2006 - up to now	Enterprise 2.0 as community	Social software and online networks	Teaching techniques with use of Enterprise 2.0
3.	2007 - up to now	Enterprise 3.0 as organization	Online networks	Practice of the Enterprise 3.0 curriculum
4.	2010 - up to now	Enterprise 4.0 as society	Ambient intelligence, WebOS or Web operating system, artificial intelligence	University Degree

Enterprise 3.0 demonstrates the technology of online networks to assemble and manage large communities with a common interest in peer contribution, where organisations and enterprises have made use of the potential of Web 3.0 with single solutions such as online networks. However, Enterprise 4.0 as shown in Table 3 will be derived from the full application of Web 4.0 concepts such as ambient intelligence, WebOS or Web operating system, artificial intelligence, rather than Web 3.0 point solutions. It should be mentioned that the concept of a Web operating system or WebOS is distinct from Internet operating systems. Web operating system or WebOS is independent of the traditional individual computer operating system. This remains as an open point for the future.

Another direction of further research might include Enterprise 2.0 application based on five phases of the process of teaching and learning: teaching in Phase 1, teaching with elements of peer-learning in Phase 2, peer-learning in Phase 3, peer-learning with elements of leaning in Phase 4 and learning in Phase 5. Thus, the present contribution has proposed analysis of efficiency of engineering curriculum in the context of sustainable development underpinning elaboration of pedagogical guidelines on the development of students' social responsibility in engineering education and directions of further research.

List of References

1. Abasheva, C. (2010) Specifics of the English Language Education in the Study Groups with Different Mother Tongues. 5th International scientific conference *Theory for Practice in the Education of Contemporary Society* of Riga Teacher Training and Educational Management Academy 25 - 27 March 2010, Riga, Latvia, pp. 428-431.
2. Allenby, B., Folsom Murphy, C., Allen, D., Davidson, C. (2009) *Sustainable engineering education in the United States*, Sustainability Science (2009) 4:7–15, Integrated Research System for Sustainability Science, Springer.
3. Barry, A. K. (2002) *Linguistic Perspectives on Language and Education*. The USA: Greenwood Publishing Group Inc.
4. Bluma, D. (2008) Teacher Education in the Context of Bologna Process. ATEE Spring University Conference *Teacher of the 21st Century: Quality Education for Quality Teaching* University of Latvia, May 2-3, 2008, P. 673-680 Riga, Latvia.
5. Blunden, A. (2009) *An Interdisciplinary Concept of Activity*. Retrieved 29/11/2009 from http://lchc.ucsd.edu/MCA/Paper/ Outlines Nr. 1 2009, 1-18.

6. Boev, O.V., Kriushova, A.A., Kulyukina, E.S., Surygin, A.S., Freeston, I., Heitmann, G., Chuchalin, A.I. (2011). *Guidelines on engineering curriculum design aligned with the European Qualification Framework and European standards for quality assurance of engineering education* / Edited by O.V. Boev, N. Gruenwald and G. Heitmann. – Tomsk: TPU publishing house, 2011.
7. Boev, O. V. (2011) *Engineering Curriculum Design: Methodology and Evaluation.* Paper presented at the Workshop on Curriculum Design in the Lucian Blaga University of Sibiu (Sibiu, Romania), October 10-12, 2011.
8. Clift, R. (1998) Engineering for the environment: the new model engineer and her role, *IChemE Transactions*, Vol. 76B, pp. 151-60.
9. Cohen, L., Manion, L., et al. (2003). *Research Methods in Education*. London and New York: Routledge/Falmer Taylor & Francis Group.
10. Commission of the European Communities. (2006). *Efficiency and Equity in European Education and Training Systems.* Communication from the Commission to the Council and to the European Parliament. Brussels 08/09/2006. Retrieved July, 3, 2010, http://ec.europa.eu/education/policies/2010/doc/comm481_en.pdf .
11. Davies, S., Edmister, J., Sullivan, K. and West, C. (2003) Educating sustainable societies for the twenty-first century, *International Journal of*
12. Flick, U. (2004) Design and Process in Qualitative Research. In U. Flick, E. Von Kardoff and I. Steine (Eds), *A Companion to Qualitative Research* (pp. 146-152). SAGE, UK, Glasgow.
13. Flyvbjerg, B. (2006) Five Misunderstandings About Case-Study Research. *Qualitative Inquiry* Volume 12(2) April 2006, 219-245. Sage Publications.
14. Gigerenzer, G. (2004) *Mindless Statistics*. The Journal of Socio-Economics, Volume 33, Issue 5, 587-606. Elsevier Inc.
15. Hahele, R. (2005). *Students' Self' — Assessment in Biology Lessons.* Synopsis of unpublished doctoral dissertation, University of Lavia, Rīga, Latvia: Latvijas Universitāte.
16. Kardoff, E. (2004) Qualitative Evaluation Research. In U. Flick, E. Von Kardoff and I. Steinke (Eds), *A Companion to Qualitative Research,* (pp. 137-142). SAGE, UK, Glasgow.
17. Leont'ev, A. N. (1978) *Activity, Consciousness, and Personality*. Prentice-Hall.
18. Lopez, C., Salmeron, J. (2011) A Framework for Classifying Risks in ERP Maintenance Projects. *Proceedings of International Conference on e-Business* (ICE-B 2011), July 18-21, 2011, pp. 201-204. Publisher: SciTePress - Science and Technology Publications, Seville, Spain.
19. Luka, I. (2008). Students and the educator's co-operation as a means of development of students' English for Specific Purposes competence. Paper presented at the European Conference on Educational Research "*Theory and Evidence in European Educational Research"*, University of Goteborg, 10-12 September 2008. Retrieved December 3, 2011, from http://www.leeds.ac.uk/educol/documents/172916.htm .
20. Luka, I., Ludborza, S., Maslo, I. (2009) Effectiveness of the use of more than two languages and quality assurance in European interuniversity master studies. *European Conference on Educational Research*, University of Vienna, September 28-30, 2009. Retrieved December 3, 2011, from http://www.leeds.ac.uk/educol/documents/186418.pdf .
21. Maslo, E. (2007). Transformative Learning Space for Life-Long Foreign Languages Learning. In D.Cunningham, D.Markus, J.Valdmanis ... [u.c.] (Eds), International Nordic-Baltic Region Conference of FIPLV *Innovations in Language Teaching and Learning in the Multicultural Context* 15-16 June, 2007, Riga, Latvia (pp. 38-46). - Rīga: SIA "Izglītības soļi".
22. Mayring, P. (2004) Qualitative Content Analysis. In: U. Flick, E. Von Kardoff and I. Steinke (Eds). *A Companion to Qualitative Research,* pp. 266-269. SAGE, UK, Glasgow.
23. Mayring, P. (2007) On Generalization in Qualitatively Oriented Research. Forum Qualitative Sozialforschung / Forum: *Qualitative Social Research*, 8(3), Art. 26, http://nbn-resolving.de/urn:nbn:de:0114-fqs0703262.
24. Oganisjana, K., Koke, T. (2008) Developing Students' Enterprise. In Maslo, I., Kiegelmann, M., Huber, G. L. (Ed.), *Qualitative Psychology in the Changing Academic Context (*pp. 218-233). Tübingen, Germany.
25. Okoli, C., Pawlovski, S. (2004) The Delphi Method as a Research Tool: an example, design considerations and applications. *Information and Management*, 42(1), 15-29. 2004.
26. Perdan, S., Azapagic, A. and Clift, R. (2000) Teaching sustainable development to engineering students*, International Journal of Sustainability in Higher Education*, Vol. 1, No. 3, pp. 267-79.
27. Philippou, S. (2005) The "Problem" of the European Dimension in Education: a principled reconstruction of the Greek Cypriot curriculum. *European Educational Research Journal*, Volume, 4(4), 343-367.
28. Portelli, J. P., Vilbert, A. B. (2002a) A Curriculum of Life. *Education Canada* Volume 42 (2), 36-39. Published by Canadian Education Association.
29. Portelli, J. P., Vilbert, A. B. (2002b) Standards, Equity, and the Curriculum of Life. *Analytic Teaching* Volume 22(1), 4-19. The Community of Inquiry Journal Published By Viterbo University LA CROSSE, WI.
30. Reich, K. (2005) *Systemisch-konstruktivistische Pädagogik*. Weinheim u.a. (Beltz), 2005, pp. 299.
31. Robbins, D. (2007) Vygotsky's and Leontiev's Non-classical Psychology Related to Second Language Acquisition. In: D.Cunningham, D.Markus, J.Valdmanis ... [u.c.] (Eds). *International Nordic-Baltic Region Conference of FIPLV Innovations in Language Teaching and Learning in the Multicultural Context*, 15-16 June, 2007, Riga, Latvia, - Rīga: SIA "Izglītības soļi", 2007. CD-ROM. pp. 47-57.
32. Rohweder, L. (2007) What kind of Sustainable Development do we talk about? In: Kaivola, T. and Rohweder, L. (Ed.), *Towards Sustainable Development in Higher Education – Reflections,* pp. 22-27. Helsinki University Press, Finland, 2007.
33. Surikova, S. (2007). Development of Criteria, Indicators and Level System for Evaluation of Enhancement of Primary School Students' Social Competence. In Proceedings of the International Scientifical Conference *Society, Integration, Education* of Rezekne Higher Education Institution (pp. 383-393). Rēzekne, Latvia: Rēzeknes Augstskola.
34. Taoussanidis, Nikolaos, (2010) *Sustainable engineering education: justified and justifiable*, Proceedings of the 7th WSEAS Int. Conf. on Engineering Education (EDUCATION '10), Corfu Island, Greece, July 22-24, 2010 pp.428-434.
35. United Nations General Assembly (1987) *Report of the World Commission on Environment and Development*: Our Common Future. Transmitted to the General Assembly as an Annex to document A/42/427 - Development and International Co-operation: Environment. Accessed in: 2009-02-15 at: http://www.un-documents.net/wced-ocf.htm.
36. Vossen, G. (2009). Web 2.0: a Buzzword, a serious Development, just Fun, or What? In Joaquim Filipe, David A. Marca, Boris Shishkov, Marten van Sinderen (Eds.), ICE-B 2009 - *Proceedings of the International Conference on e-Business*, Milan, Italy, July 7-10, 2009, ICE-B is part of ICETE - The International Joint Conference on e-Business and Telecommunications *(*pp. 33-40). Milan, Italy: INSTICC Press 2009.
37. Vygotsky, L. (1934/1962) The Development of Scientific Concepts in Childhood. Reading Pack No 4.1d: In: L. S.Vygotsky, *Thought and language* (82-97). 1934/1962. Cambridge, MS: MIT. 287 p.
38. Wells, G. (1994) *Learning And Teaching "Scientific Concepts".* Moscow, Sept. 1994. Vygotsky's Ideas Revisited. Ontario Institute For Studies In Education. University Of Toronto. Retrieved 01/07/2010 from http://education.ucsc.edu/faculty/gwells/Files/Papers_Folder/Scient.concepts. pp. 10.

УСТОЙЧИВОЕ РАЗВИТИЕ В ИНЖЕНЕРНОМ ОБРАЗОВАНИИ: ПЕДАГОГИЧЕСКИЙ ПОДХОД

Андреас Аренс и Елена Защеринская

А н н о т а ц и я

Инженерное образование сталкивается с проблемой развития социальной ответственности в контексте устойчивого развития. Целью исследования является анализ продуктивности инженерных учебных программ в контексте устойчивого развития для разработки педагогического руководства по развитию социальной ответственности студентов-инженеров в инженерном образовании. Анализ включает в себя процесс анализа смысла ключевых понятий *устойчивого развития* и *инженерные учебные программы*. Кроме того, исследование демонстрирует как ключевые понятия связаны с идеей продуктивности. Исследование качественной оценки было использовано. Эмпирические исследования были проведены в Балтийской Летней школе "Техническая информатика и информационные технологии" в 2009, 2010 и 2011 годах. 85 участников приняли участие в опросе для эмпирических исследований. Потребности студентов в Enterprise 2.0 были критериями продуктивности инженерных учебных программ в контексте устойчивого развития. Описательная статистика была реализована для первичного анализа данных. Результаты исследования позволяют сделать вывод о продуктивности инженерных учебных программ для развития социальной ответственности студентов-инженеров в контексте устойчивого развития. педагогического Руководство по развитию социальной ответственности студентов-инженеров в инженерном образовании предложено.