A METHODOLOGY OF EVALUATION OF EFFICIENCY OF ENGINEERING CURRICULUM IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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ABSTRACT: Engineering education is facing a challenge of evaluation of efficiency of engineering curriculum for the development of student engineers' social responsibility in the context of sustainable development. Traditionally, engineering curriculum is assessed. However, the concept of sustainable development has changed the paradigm in education from assessment to evaluation of efficiency of engineering curriculum. Aim of the research is to analyze the methodology of evaluation of efficiency of an engineering curriculum in the context of sustainable development. The meaning of the key concepts of *efficiency, self-evaluation, internal evaluation, external evaluation* and *methodology* is studied. Moreover, the study indicates how the steps of the process are related: efficiency of engineering curriculum → evaluation of efficiency of engineering curriculum → methodology of evaluation of efficiency of engineering curriculum → empirical study within a multicultural environment. The qualitative evaluation research has been used. The empirical study was conducted within the Seventh Baltic Summer School *Technical Informatics and Information Technology*, August 12-27, 2011, Riga, Latvia. The theoretical findings of the present research allow elaborating the methodology of evaluation of efficiency of engineering curriculum for the development of students' social responsibility. The empirical findings allow drawing conclusions on the efficiency of the engineering curriculum.

1. INTRODUCTION

Engineers were once able to initiate engineering projects, able to transform real needs into design and, finally, material form [25]. However, the social responsibility of engineers has become topical in the context of sustainable development and places high demands on engineering education. Higher education bears a significant responsibility for sustainability by virtue of its influence on society and academic freedom to explore ideas [7]. Therein, responsibility is defined as the ability to evaluate, to analyze, to choose and to work professionally in new and unknown situations [16].

Engineering education has attracted a lot of research efforts on the development of student engineers' social responsibility in the context of sustainable development [2]. The research demonstrates the shift in engineering education in the context of sustainable development from the conventional engineering curriculum limited to techno-economic issues [25] to the curriculum centred on the inter-relationship between engineering and economic, social and environmental dimensions of life as shown in Figure 1, thereby developing student engineers' social responsibility.

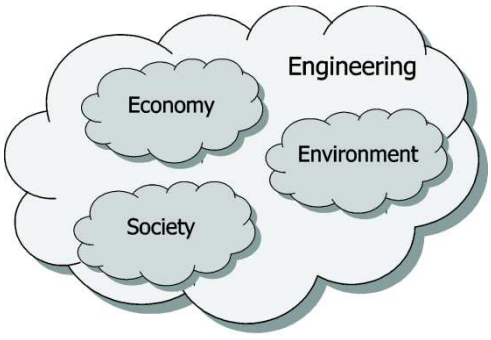

Figure 1. Engineering and dimensions of life.

Application of engineering innovations in one of the dimensions affects the other two dimensions. Therein, students' social responsibility is defined as students' ability to act professionally in the system of economic, social and environmental interrelations, thereby contributing to the sustainable development. Thus, the economic dimension has already changed from the traditional commercial activity to the Internet enabled business. In its turn, speeding up service delivery and distribution-tracking capabilities leads to changes in social and environmental dimensions that include transition from an input based to an outcome based [3] teaching/learning process in engineering curriculum. These organizational changes in complex and constantly self-regenerating environments [12] put a greater emphasis on the methodology of evaluation of efficiency of engineering curriculum in the context of sustainable development rather than assessment.

Aim of the research is to analyze the methodology of evaluation of efficiency of an engineering curriculum in the context of sustainable development.

The meaning of the key concepts of *efficiency, self-evaluation, internal evaluation, external evaluation* and *methodology* is studied. Moreover, the study indicates how the steps of the process are related: efficiency of engineering curriculum → evaluation of efficiency of engineering curriculum → methodology of evaluation of efficiency of engineering curriculum → empirical study within a multicultural environment.

The remaining part of this paper is structured as follows: Section 2 introduces the theoretical framework on the methodology of evaluation of efficiency of engineering curriculum in the context of sustainable development. The associated results of the empirical study will be presented in Section 3. Finally, some concluding remarks are provided followed by a short outlook on interesting topics for further work.

2. THEORETICAL FRAMEWORK

The theoretical framework of the paper involves the meaning of the key concepts of *efficiency*, *evaluation* and *methodology* studied.

2.1. Engineering Curriculum in the Context of Sustainable Development

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 [26]. Sustainable development aims to achieve three types of approaches to solving the three categories of objectives: economic, social, environmental as shown in Figure 2.

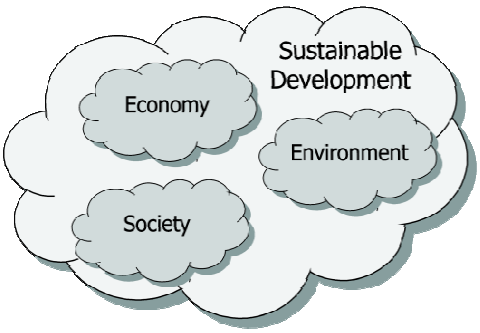

Figure 2. Dimensions of sustainable development.

Thus, sustainable personality is "a person who sees relationships and inter-relationships between nature, society and the economy" [24].

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 [25]. 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" [4] with a "broad understanding of the social and philosophical context in which he will work" [21].

In engineering education curriculum is a central, organizing stance [22]. 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 as demonstrated in Figure 3.

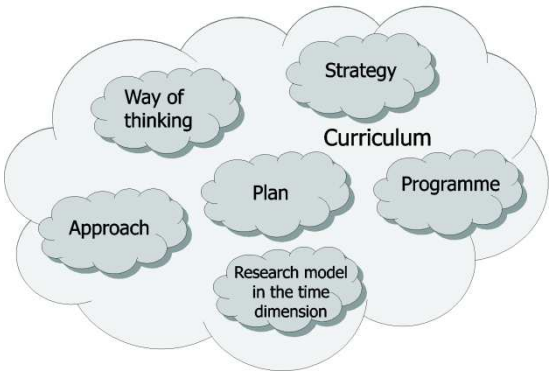

Figure 3. Inter-relationship between the terms of curriculum.

Curriculum comprises the following components: aim, objectives, content, process of teaching and learning as well as evaluation as depicted in Figure 4.

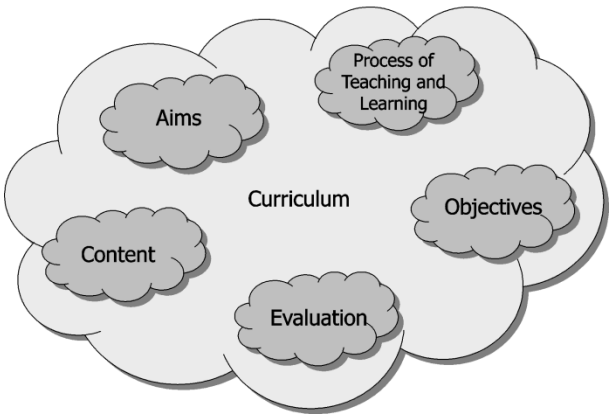

Figure 4. Curriculum components.

2.2. Efficiency of Engineering Curriculum

Efficiency of engineering curriculum involves quality and effectiveness as depicted in Figure 5.

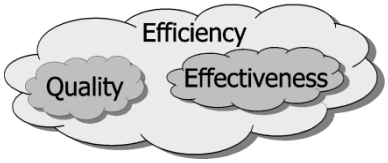

Figure 5. Elements of efficiency.

Quality is regarded as the improvement of student engineers' knowledge, skills and attitudes [28] as shown in Figure 6.

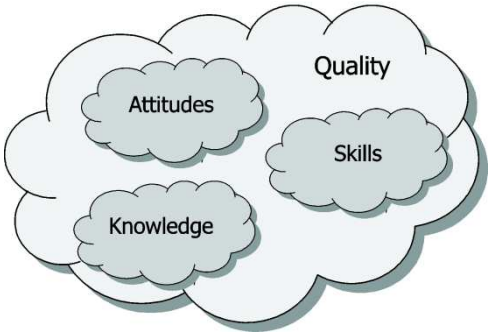

Figure 6. Elements of curriculum quality.

In turn, effectiveness is defined as the educator's contribution to the student engineers' knowledge, skills and attitudes [28].

Curriculum is efficient if the inputs (curriculum) produce the maximum output (students' knowledge, skills and attitudes) [6]. Therein, students' knowledge, skills and attitudes are the outcome criterion of efficiency of engineering curriculum. Further on, students' knowledge, skills and attitudes are the criterion of students' social responsibility.

Analysis of efficiency of curriculum includes the comparison of the inputs with the outputs, in other words – assessment, and the context analysis in which the curriculum is implemented, in other words – evaluation.

2.3. Evaluation of Efficiency of Engineering Curriculum

By evaluation, the process of examination and its results are determined.

It should be noted that evaluation includes assessment as demonstrated in Figure 7.

Figure 7. Inter-connections between evaluation and assessment.

Traditionally, assessment reveals student advancement, placement and grades. In its turn, evaluation provides feedback on the worth or value of a course, module or curriculum. Moreover, evaluations often utilize assessment data along with other resources to make decisions about revising, adopting, or rejecting a course, module or curriculum.

Evaluation includes self-evaluation, internal evaluation and external evaluation [10] as depicted in Figure 8.

Figure 8. Elements of evaluation.

Self-evaluation is usually used by the students of a course, module or curriculum. Internal evaluation involves internal evaluators, namely, engineering students and educators of the education institution [10]. External evaluation is traditionally presented by experts. By expert a professional who obtains extensive experience based on research in a particular area of study is meant. The choice of experts is based on two criteria, namely, recognized knowledge in the research topic and absence of conflict of interests [13] as shown in Figure 9.

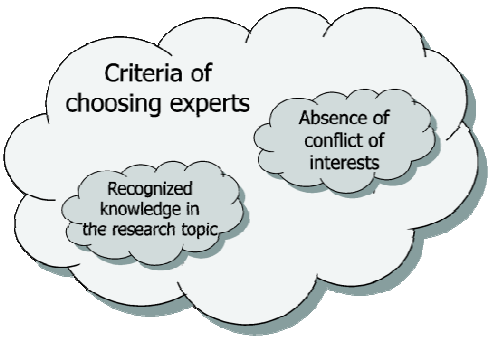

Figure 9. Criteria of choosing experts for external evaluation.

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 [20]. Thus, 10 is a good number of experts for the study [13].

2.4. Methodology of Evaluation of Efficiency of Engineering Curriculum

Methodology is defined as a system of principles, practices, and procedures applied to any specific branch of knowledge [11].

Hence, Figure 10 illustrates the components of methodology.

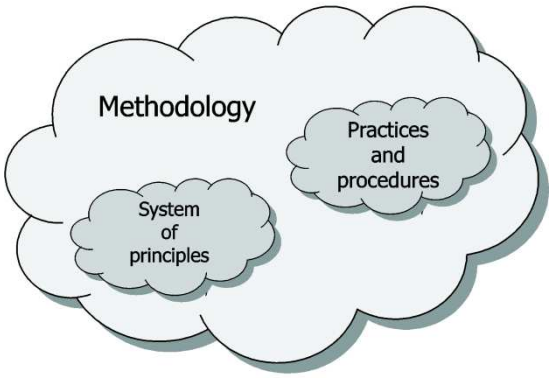

Figure 10. Components of methodology.

Table 1 presents the system of the key principles of evaluation of efficiency of engineering curriculum in the context of sustainable development.

Table 1. The system of the key principles of evaluation of efficiency of engineering curriculum

Key principles	Mutual Sustainability
	Mutual Complementarity
	Mutual Reflexivity
Development of the inter-relationships between engineering and economic, social and environmental dimensions of life	

Evaluation of efficiency of engineering curriculum in the context of sustainable development proceeds from self-evaluation in Phase 1 to external evaluation in Phase 3 through internal evaluation in Phase 2 as shown in Figure 11.

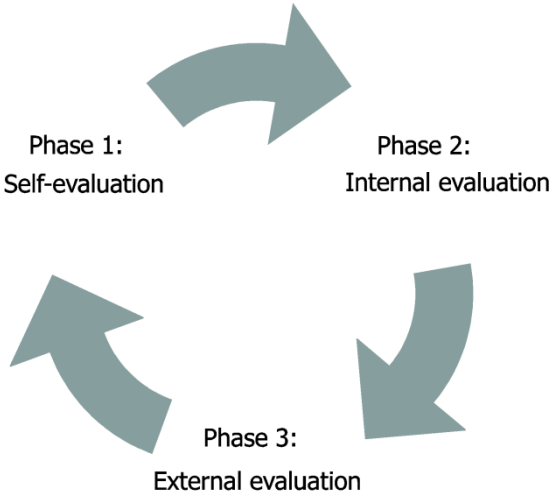

Figure 11. Methodology of evaluation of efficiency of engineering curriculum

3. EMPIRICAL RESEARCH

The empirical research includes the research design and analysis of the pre- and post-survey.

3.1. Research Design

The design of the present empirical research comprises the purpose and question, sample 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 Enterprise 2.0 application in the engineering curriculum been efficient? The present research involves 35 respondents, namely

- 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 the 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 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' learning outcomes in Enterprise 2.0 application [15]. It should be also noted that whereas cultural similarity aids mutual understanding between people [23], 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 such as appropriate materials, teaching/learning methods and forms, motivation and friendly positioning of the educator [1]. 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 [14] has been determined. Interpretative paradigm is characterized by the researchers' practical interest in the research question [5].

Figure 12 shows how the qualitative evaluation research proceeded. The qualitative evaluation research moved from the phase of exploration of the context analysis through the description of the practice to the phase of generalization of the model. The phase of exploration of the context analysis is aimed at determining the present situation in Enterprise 2.0 application in the engineering curriculum for promoting students' motivation and their readiness to implement the joint activity. The phase of the description of the practice analyzes differences in levels of features analyzed. And the phase of generalization of the model evaluates efficiency of Enterprise 2.0 application in the engineering curriculum for the development of students' knowledge, skills and attitudes.

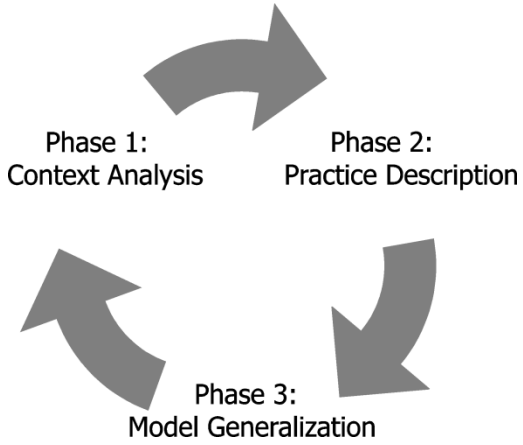

Figure 12. Phases of the qualitative evaluation research.

The qualitatively oriented research allows the construction of only few cases [17]. Moreover, the cases themselves are not of interest, only the conclusions and transfers we can draw from these respondents [17]. Selecting the cases for the case study comprises use of information-oriented sampling, as opposed to random sampling [8]. 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 [8]. 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.

3.2. Pre-Survey

The present part of the empirical study reveals analysis of engineering students' learning outcomes in Enterprise 2.0 application within the engineering curriculum of the Baltic Summer School *Technical Informatics and Information Technology* in 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* has been taking part in the Baltic States since 2005. The International Summer School offers special courses to support the internationalization of education and cooperation among the universities of the Baltic Sea Region in the context of sustainable development. The goal of studies in the Baltic Summer School *Technical Informatics and Information Technology* is to prepare the students 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. The Baltic Summer School *Technical Informatics and Information Technology* contains a special module on Web 2.0 that includes Enterprise 2.0. 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 [27] as shown in Figure 13.

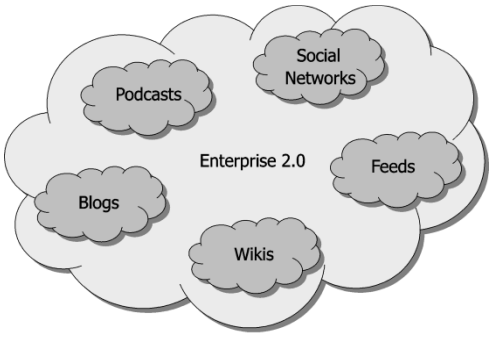

Figure 13. Elements of Enterprise 2.0.

Analysis of the students' feedback regarding their needs for 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 "0" means "no" and "1" - "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 "0" means "no" and "1" - "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 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 Enterprise 2.0 application and "3" points out a high level of Enterprise 2.0 application.

The pre-survey results of needs for Enterprise 2.0 application reveal that the student engineers do not realize the possibilities offered by Enterprise 2.0 for business 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 students - 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 following model of Enterprise 2.0 application in engineering curriculum implemented within the Baltic Summer School *Technical Informatics and Information Technology* in the context of sustainable development:

- 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 [19].
- 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 [22] by providing innovative opportunities and organizing student engineers' cognitive activity.
- Measurable learning outcomes are defined as
  a) student engineers' knowledge of the Enterprise 2.0 concept,
  b) student engineers' skills to use Enterprise 2.0,
  c) student engineers' attitude towards their 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 - 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:
  a) 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.
  b) 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.
  c) 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.
- Evaluation of achievement of learning outcomes and curriculum objectives comprises student engineers' self-evaluation, internal evaluation and external evaluation [10].

3.3. Post-Survey

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 five, 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 the engineering curriculum of the Baltic Summer School *Technical Informatics and Information Technology* in 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 the Enterprise 2.0 application, analysis of the engineering students' self-evaluation comprised the structured interviews of three questions:

a) What is your attitude to the Enterprise 2.0 application?
b) What have you learned?
c) How can you apply this knowledge in your professional field?

The aim of the interviews was to reveal the engineering students' evaluation of the Enterprise 2.0 application for the development of student engineers' learning outcomes. The student engineers' expressions from the structured interviews were systematized according to two constructs: the construct of positive evaluation and the construct of negative evaluation.

Comparing the answers of those 24 engineering students in the sample, the structured interviews focused on the engineering students' positive experience in the Enterprise 2.0 application. For example**,** a student reveals the inter-relationship between the positive experience of social interaction and cognitive activity in the Enterprise 2.0 application: "I feel this class to be very useful to me because I am improving my knowledge in the 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".

The data were processed applying AQUAD 6.0 software. The determined constructs were systematized into the codes corresponding to a construct, namely, positive and negative evaluation.

Most of the student engineers' expressions were categorized to the construct *Positive Evaluation*. Frequencies were determined to reveal the student engineers' evaluation. The survey showed that the student engineers have given their positive evaluation to the engineering curriculum as demonstrated in Table 2.

Table 2. Frequency of student engineers' evaluation.

Construct	Construct domain	Number	Percentage
Evaluation	Positive evaluation	24	100%
	Negative evaluation	0	0%

Summarizing content analysis [18] of the structured interviews demonstrates that the Enterprise 2.0 application in the engineering curriculum promotes the development of students' learning outcomes. Moreover, the 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 [10]. Analysis of the 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, comparison of the pre-survey and post-survey results was carried out. The *Mean* results of the descriptive statistics highlighted in Table 3 demonstrate that the level of the students' learning outcomes has increased in the post-survey (1,93) in comparison with the pre-survey (1,67).

Table 3. Mean analysis of the pre- and post-survey in 2011.

Question	Pre-survey	Post-survey
1	0,04	0,04
2	0,45	0,66
3	3,83	4,21
4	2,37	2,79
Mean	**1,67**	**1,93**

The results of *Mean* within the surveys of the students' feedback regarding their needs for Enterprise 2.0 application reveal that most of the 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 [9], the conclusion has been drawn that the Enterprise 2.0 application in the engineering curriculum 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 10 researchers from different countries were involved. It should be mentioned that all the researchers who 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 the 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. External evaluation of the Enterprise 2.0 application in the engineering curriculum comprised non-structured interviews of one question as following: What is the researcher's view on the Enterprise 2.0 application for the development of engineering students' learning outcomes? The aim of the non-structured interviews was to reveal the researchers' evaluation of the Enterprise 2.0 application for the development of engineering students' learning outcomes.

The experts' expressions from the non-structured interviews were systematized according to two constructs: the construct of positive evaluation and the construct of negative evaluation.

For example, a respondent considered the organization model of the 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,
- viewing the overall personality of the learner,
- the fact that educators can indeed change the typical classroom environment,
- developing newer constructs that will truly help the student to internalize new material and
- the student having the "ability to create knowledge".

The data were processed applying AQUAD 6.0 software. The determined constructs were systematized into the codes corresponding to a construct, namely, positive and negative evaluation. Most of the experts' expressions were categorized to the construct *Positive Evaluation*. Frequencies were determined to reveal the experts' evaluation. The survey showed that the experts had given their positive evaluation to the engineering curriculum most frequently as shown in Table 4.

Table 4. Frequency of experts' evaluation.

Construct	Construct domain	Number	Percentage
Evaluation	Positive evaluation	10	100%
	Negative evaluation	0	0%

Summarizing content analysis [18] of the data reveals that the respondents have positively evaluated the Enterprise 2.0 application for the development of engineering students' learning outcome in the engineering curriculum. Thus, the conclusion can be drawn that the Enterprise 2.0 application enhances development of engineering students' learning outcomes.

conclusions

The theoretical findings of the present research allow drawing the conclusion that the proposed methodology serves as a tool for evaluation of efficiency of engineering curriculum for the development of students' learning outcomes and, consequently, students' social responsibility. It means that the methodology of evaluation of efficiency of engineering curriculum corresponds to the theoretical conceptions of the development of students' learning outcomes.

The findings of the empirical study allow drawing the conclusions on the efficiency of the Enterprise 2.0 application in the engineering curriculum for the development of the student engineers' learning outcomes. 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, the Enterprise 2.0 application has become an effective means of acquiring social experience by the engineering students in order to improve their learning outcomes. The Enterprise 2.0 application resulted in the improved engineering students' learning outcomes. Therein, the 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 the Enterprise 2.0 application. The engineering students' social experience and attitude are positive. That shows that the Enterprise 2.0 application in engineering curriculum influences 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 the Enterprise 2.0 application in the engineering curriculum validates the findings of the present research.

Thus it might be stressed that engineering curriculum 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 in engineering curriculum - 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 the 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 – methodology of evaluation of efficiency of engineering curriculum, the definition of students' social responsibility, the Enterprise 2.0 application in engineering curriculum and the qualitative evaluation research design - may be used as a basis of analysis of efficiency of engineering curriculum 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.

Further research might include analysis of engineering curriculum 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 learning in Phase 4 and
- learning in Phase 5.

Thus, the present contribution has proposed analysis of the methodology of evaluation of efficiency of engineering curriculum in the context of sustainable development and directions of further research.

REFERENCES

1. Abasheva, C., 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*, Riga Teacher Training and Educational Management

Academy 25 - 27 March, pp. 428-431, Riga, Latvia (2010).
2. Allenby, B., Folsom Murphy, C., Allen, D., Davidson, C., Sustainable engineering education in the United States. *Sustainability Science* 4, pp.7–15. Integrated Research System for Sustainability Science, Springer (2009).
3. Bluma, D., 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, pp. 673-680, Riga, Latvia, (2008).
4. Clift, R., Engineering for the environment: the new model engineer and her role, *IChemE Transactions*, Vol. 76B, pp. 151-60, (1998).
5. Cohen, L., Manion, L., et al. *Research Methods in Education*. London and New York: Routledge/Falmer Taylor & Francis Group, (2003).
6. Commission of the European Communities, *Efficiency and Equity in European Education and Training Systems.* Communication from the Commission to the Council and to the European Parliament. Brussels, Belgium, (08/09/2006).
7. Davies, S., Edmister, J., Sullivan, K. and West, C., Educating sustainable societies for the twenty-first century, *International Journal of Sustainability in Higher Education*, Volume 4 (2), pp. 169-180. Emerald Publishing, (2003).
8. Flyvbjerg, B., Five Misunderstandings about Case-Study Research. *Qualitative Inquiry*, Volume 12, No. 2, April 2006, pp. 219-245, Sage Publications, (2006).
9. Gigerenzer, G., Mindless Statistics. The Journal of *Socio-Economics*, Volume 33, Issue 5, pp. 587-606. Elsevier, (2004).
10. Hahele, R., *Students' Self - Assessment in Biology Lessons.* Synopsis of unpublished doctoral dissertation, University of Latvia, Riga, Latvia, (2005).
11. Karapetjana, I., English for Specific Purposes Teaching Methodology. Akadēmiskais apgāds of the University of Latvia, Riga, Latvia, (2008).
12. Kardoff, E., Qualitative Evaluation Research. In U. Flick, E. Von Kardoff and I. Steinke (Eds), *A Companion to Qualitative Research*, pp. 137-142, SAGE, Glasgow, UK, (2004).
13. Lopez, C., Salmeron, J., A., Framework for Classifying Risks in ERP Maintenance Projects. *Proceedings of International Conference on e-Business* (ICE-B 2011), July 18-21, pp. 201-204, Seville, Spain, (2011).
14. Luka, I. Students and the Educator's Co-Operation as a means of Development of Students' English for Specific Purposes Competence. European Conference on Educational Research "*Theory and Evidence in European Educational Research"*, University of Goteborg, 10-12 September, Leeds, UK, (2008).
15. Luka, I., Ludborza, S., Maslo, I., 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, Leeds, UK, (2009).
16. Maslo, I., New-professionalism's responsibility of learning in socio-cultural educational contexts. German Institute of Adult Education, Bonn, Germany, (2009).
17. Mayring, P., On Generalization in Qualitatively Oriented Research. Forum: *Qualitative Social Research*, Volume 8, No.3, Art. 26, pp. 1-8, (2007).
18. Mayring, P., Qualitative Content Analysis. In Flick, U. von Kardoff, E. and Steinke. I. (Eds). *A Companion to Qualitative Research*, pp. 266-269, SAGE, Glasgow, UK, (2004).
19. Oganisjana, K., Koke, T., Developing Students' Enterprise. In Maslo, I., Kiegelmann, M., Huber, G. L. (Ed.), *Qualitative Psychology in the Changing Academic Context*, pp. 218-233, Tübingen, Germany, (2008).
20. Okoli, C., Pawlovski, S., The Delphi Method as a Research Tool: An Example, Design Considerations and Applications. *Information and Management*, Volume 42, No. 1, pp. 15-29, (2004).
21. Perdan, S., Azapagic, A. and Clift, R., Teaching sustainable development to engineering students, *International Journal of Sustainability in Higher Education*, Vol. 1, No. 3, pp. 267-79, (2000).
22. Portelli, J. P., Vilbert, A. B., Standards, Equity, and the Curriculum of Life. *Analytic Teaching* Volume 22, No. 1, pp. 4-19. The Community of Inquiry Journal Published By Viterbo University LA CROSSE, WI, (2002).
23. Robbins, D., Vygotsky's and Leontiev's Non-classical Psychology Related to Second Language Acquisition. In: Cunningham, D., Markus, D., Valdmanis, J., [u.c.] (Eds). *International Nordic-Baltic Region Conference of FIPLV Innovations in Language Teaching and Learning in the Multicultural Context*, pp. 47-57, Riga, Latvia, - Rīga: SIA "Izglītības soļi", (2007).
24. Rohweder, L., 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).
25. Taoussanidis, Nikolaos, 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, (2010).
26. United Nations General Assembly, *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, (1987).
27. Vossen, G., Web 2.0: a Buzzword, a serious Development, just Fun, or What? *Proceedings of International Conference on e-Business*, Milan, Italy, July 7-10, pp. 33-40, (2009).
28. Zaščerinska, J., Social Dimension of Web 3.0 in Engineering Education. In Bassus, O.; Ahrens, A.; Lange, C. (Ed.), *Information and Communication Technologies in Engineering and Business*, pp. 101-130, Berlin: Mensch & Buch, Germany, (2011).