DESIGN OF THE CURRICULUM FOR CONTINUING EDUCATION OF ENGINEERING EDUCATORS AT TALLINN UNIVERSITY OF TECHNOLOGY

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Abstract

Curriculum development for continuing education of engineering educators has been of essential importance in Estonian Centre for Engineering Pedagogy. The curriculum has been completed in 2010. The newly designed curriculum makes scientifically-founded and practice-oriented teacher training possible. A three-staged methodology in curriculum design has been used. The proposed methodology for the course design starts with decisions on overall goals, learning objectives and intended learning outcomes. The design followed the model: Establish Qualification Profile, Establish Admission Quality, Define Course Content, Establish the Curriculum at Macro Level, Establish the Curriculum at Micro Level, Integrate the Curriculum within the University System, the syllabus and the model is described more closely in the article. Eight possible specializations have been proposed. As the required entrance qualification of the candidate is Master degree in engineering, it is assumed that the candidate has acquired a complete knowledge in engineering speciality on high level afore. The curriculum is based on IGIP (International Society for Engineering Education) Recommendations for Studies in Engineering Pedagogy Science and described in detail, being the only and the very first one in Estonia providing continuing education in Engineering Pedagogy for engineers. The first students will be admitted to the pilot study programme in 2011.
Key words: *continuing education, curriculum design, engineering education.*

Introduction

Education is a dynamic phenomenon, recognising the changes in the environment and respond to growing demands and challenges. Engineering education is a large system and it is almost impossible to predict its behaviour over far too distant future since the system parameters show a high rate of change. Changes in society present challenges to education. In order to educate not reactors to changes but, first and foremost, directors and executors of changes, it is important to promote the development of corresponding attitudes and skills in the students. These skills and attitudes in engineering education are developed with the support of the key person – an engineering educator. Without changing the education of engineering educators we cannot bring about changes in the overall educational system of engineering.

According to John Heywood (Heywood, 2005) curriculum is a formal mechanism through which intended educational aims are achieved. Since educational aims are achieved through learning, the curriculum process is described by those factors that bring about learning. Thus, both learning and instruction are central to the process of curriculum design.

Accordingly to Kelly (2009) one feature that characterized the curriculum change of recent years is the increased incidence of planning and preparation in curriculum development. Over the last three decades, or even more, educationists have begun to see the need for planned innovation, to recognise that the educational change is to keep pace with and match changes in society, if it is at the same time to maintain also those standards and values which may be seen as transcending particular times and particular societies, and if it is to respond to that increased understanding of education and curriculum which has come from recent work in the field of Curriculum Studies, it must be deliberately managed rather than merely left to happen.

The content of what we expect students to learn during their studies is clearly a crucial element in curriculum planning, whatever view we take of education, curriculum or, indeed, knowledge itself. There are important questions to be addressed, however, concerning how the knowledge content of a curriculum relates to its other dimensions.

Engineering educators should pass preliminarily higher engineering education at least on Master level and obtain solid knowledge in a certain field of engineering. Successive courses for engineering educators should not exceed a year. Length of the courses has been a key factor in the professional judgement of the standard of courses. In compliance with F. Hrdlička and J. Měřička (Hrdlička & Měřička 2006) one of the main problems of training engineering educators is the relation of engineering education and educational studies. High engineering competency is generally required which can be complemented by further educational studies. It is generally assumed that for teaching engineering particularly on post-secondary level more professional or specialised education and less educational training is required (Hrdlička & Měřička, 2006).

Continuing education of engineering educators cannot be classified as within the traditional academic categories. It cannot be compared to Bachelor-, Master- or Doctoral level, as the aim of the education is not always to obtain certain academic, theoretical level in pedagogy. Engineering educators must not only keep up with the new pedagogical demands but also with the new developments in the engineering speciality they teach; they are expected to be able to work with different target groups – young students and adult learners.

Adults learn the same way as traditional-age students, but they respond somewhat differently to certain instructor behaviours, teaching strategies, and content emphases. They are less forgiving about the instructor being poorly prepared, having questionable expertise, and not having suitable supplementary materials. They value their own life experiences (for good reason) and want to share and discuss it in small groups and as a class. As they know the world to be complex, they expect to learn multiple ways of solving problems and to have discretion in applying the material. They need the opportunity for reflection after trying out a new application or method. Adult learners are often practical; they demand that the materials have immediate utility and relevant application. None of this implies that they are difficult learners. In fact, they are highly motivated, eagerly participatory, and well prepared for class.

Pedagogical training is built on the educator' professional specialty qualification and gives the necessary theoretical and practical pedagogical, didactical and psychological competencies. According to V. Manuilov, A. Melezinek and V. Prikhodko (Manuilov, Melezinek & Prikhodko 1998) teaching will never be completely formalised, in most cases knowledge and experience of engineering educators in the field of pedagogy cannot be presupposed. The future educator at a technical school or university must acquire these skills in addition.

This article is concerned with the curriculum design for continuing education of engineering educators at Estonian Centre for Engineering Pedagogy at Tallinn University of Technology.

Proposed Methodology

Curriculum design and course development have taken a new dimension today. Engineering education is no longer guided by national goals - globalisation of higher education has a worldwide influence today. Development of science and technology has advanced so much that no individual can learn everything (Melezinek, 1999). Students often go to other countries for higher education. The background knowledge and skills of students are often different. Communication skills, ICT skills and skills of learning are of essential importance today. Design and development of courses must consider all these problems.

According to Kelly (2009) it has been suggested that the curriculum has to be seen as consisting of four elements, and curriculum planning, therefore, is having four dimensions: objectives, content or subject matter, methods or procedures and evaluation. In short, the claim is that it is important to distinguish in curriculum planning what we are hoping to achieve, the ground we are planning to cover in order to achieve it, the kinds of activity and methods that we consider likely to be the most effective in helping us towards our goals and how to evaluate what we have done. Accordingly to Kelly (2009) this analysis would give us a very simple model for curriculum planning, a linear model, which requires us to specify our objectives, to plan the content and the methods which will lead us towards them and, finally to endeavour to measure the extent of our success.

If a curriculum can, or must, be viewed in terms of these four above described elements, different planning models will emerge according to the ways in which we might per-mutate those elements, the priorities we might give to them and the choice of focus we might adopt. Within this model educational purposes take pride of place, content is selected not for its own sake but for its presumed efficacy at enabling us to achieve those purposes, organisation is similarly designed with these objectives in mind, and evaluation is framed so as to assess how far those objectives have been achieved.

Yet, according to Kelly (2009) a third model has emerged more recently, as some have placed the emphasis on the organisation of the educational experiences. This model has been described as a process model or as a developmental model. With this model, the planner begins from a concept of education as a series of developmental processes which the curriculum should be designed to promote. The selection of both content and methods or procedures is made with the promotion of these developmental processes as the central concern. And evaluation is focused both on the suitability of the content and procedures selected and on an assessment of the development which may, or may not, have occurred.

Accordingly to Rutiku & Lehtsaar (2006), ideally, the design of a curriculum proceeds through the following steps:

1. Define audience in terms of their goals (broadly stated), their preparation, both cognitive (e.g. mathematical skills) and psychological (e.g. motivation);
2. State educational aims and objectives in two stages – general (broad classes of problems to be solved by learners), and specific (set of individual skills required for problem solving);
3. Select instructional framework including scope and content of material, its plan and organisation, instructional materials, teaching methods, means of evaluation. Take into consideration learner conciderations (nature of learning process, learning abilities), subject considerations (content and structure of organised knowledge in the discipline) and administartive conciderations (limitations of time, personnel and facilities);
4. Select means, methods and criteria of assessment;
5. Assess results based on trial use and experience and suggestions from those knowledgable;

6. Revision and evolution of all named preceding steps.

The above presented designing process leads to a curriculum which consists of a set of courses. A course is a useful basic unit with which to construct the curriculum because:

1. It deals with a single or narrowly defined subject matter;
2. It represents a learning effort of a few weeks;
3. It is under the control of a small number of, and usually only one, instructor;
4. While the revision of an entire curriculum is undertaksen only after long intervals, the content of a single course evolves more frequently.

According to John Heywood (Heywood, 2005) there has been a marked reluctance to stick to the terminology related to the objectives. Today the term 'outcome' is preferred to 'objective' and some authors infer differences between objectives and outcomes that were not in the minds of those with whom the so-called 'objectives movement' is associated. Objectives are guideposts for teachers and outcomes for students. Accordingly to Guenter Heitmann (Heitmann, 2005) the paradigm shift to outcomes orientation and student learning have recently fostered the use of systematic and comprehensive approaches. Pressures on programme providers and faculty have been worldwide and caused by respective accreditation or external quality evaluation demands.

General trends in curriculum design proposed by Rutiku & Pilli (2009) have been used in the design of the curriculum for continuing education of engineering educators described in the present article. The proposed methodology for the course design started with decisions on overall goals, learning objectives and intended learning outcomes. The curriculum was designed according to the following model:

1. *Establish Qualification Profile* – expectations of employers, qualities (knowledge, skills and attitudes) the graduates would possess were considered and expressed as learning outcomes;
2. *Establish Admission Quality* – appropriate entry qualities were settled;
3. *Define Course Content* – the course content should develop communication skills, analytical capability, skills for project, research and laboratory work, the use of information technology, teaching and learning skills;
4. *Establish the Curriculum at Macro Level* – establish syllabus, teaching approaches like lectures, seminars, practical lessons, etc., and timetable;
5. *Establish the Curriculum at Micro Level* – establish module content, methods and criteria of assessments, etc.;
6. *Integrate the Curriculum within the University System* – the university should have a course approval procedure and general awarding system for Master programmes.

The Curriculum design process is a complex activity: each stage involves an iterative procedure, the output of which is evaluated before being used as a part of the input to the next stage. Specific learning strategies will be required if the objectives are to be successfully obtained, and this requires an understanding of the complexity of learning. A multiple strategy approach to teaching, learning and assessment will be required.

Effective strategies and models have been worked out and are used for teaching thinking skills and capitalizing deep understanding in teaching engineering. These strategies and models are widely used at Estonian Centre for Engineering Pedagogy at Tallinn University of Technology in teaching of engineering educators (Rüütmann, 2009a).

Contemporary teaching methods, emphasizing conceptual understanding, adapted specially for engineering education have been widely tested and switched into described study programme at Estonian Centre for Engineering Pedagogy (Rüütmann, 2009b).

Assessment of students' study outcomes has been up to dated, new assessment methods and criteria of study outcomes for all subjects have been switched into the curriculum and for

September 2010 all subjects of the syllabus should have revised and renewed assessment methods and criteria at Tallinn University of Technology accordingly to Pilli (Pilli, 2010).

According to Norbert Kraker (Kraker 2006) a successful curriculum for engineering educators meets the needs of the contemporary continuing education sector, while guaranteeing academic standards appropriate to the teaching profession. A curriculum of contemporary education of engineering educators should make scientifically-founded and practice-oriented education possible, so that engineering educators can expect to build a deeper understanding of the principles, problems and solutions associated with teaching students in technical institutions. Above mentioned scientifically proved principles served as a basis for the design of the curriculum described in the present article.

Results of the Curriculum Design

Engineering Pedagogy Studies in Estonia are provided only by Estonian Centre for Engineering Pedagogy at Tallinn University of Technology. The newly designed curriculum is the only and the very first one in Estonia providing continuing education in Engineering Pedagogy for engineering educators in the amount of 35 ECTS credits. This is the sufficient amount of credits, for preparation of engineering educators who already have acquired afore the qualification in engineering on Master level, the fact being proved accordingly by the long-term studies of International Society for Engineering Education (IGIP). The proven IGIP basic curriculum for engineering educators, in the amount of 20 ECTS credits, is based on the knowledge of traditional pedagogy in philosophy and the liberal arts but respects the particular character of the technician and the analytical-methodological approach in the fields of engineering science (more detailed information about the basic curriculum of IGIP for engineering educators could be retrieved from the webpage www.igip.org).

The newly designed curriculum at Estonian Centre for Engineering Pedagogy is based on IGIP Recommendations for Studies in Engineering Pedagogy and the basic curriculum of IGIP for engineering educators' and overcomes the recommended 20 ECTS credits of IGIP basic curriculum (IGIP 2005) due to the pre-descriptions of Estonian legislation regulating higher education. In Estonia the courses of continuing education of engineering educators start relevantly from 35 ECTS credits. The curriculum designed and described in the present article does not award Master level education, thus being only the basis for continuing education courses for engineering educators.

Students already possessing Master degree in engineering speciality and professional experience for at least one year will be admitted to the pilot course from September 2010. It is assumed that the candidate has acquired knowledge in engineering speciality on high level afore.

The structure of the curriculum is presented in Table 1. As it could be seen there are two main modules in the curriculum: Modules of Engineering Pedagogy, consisting of compulsory subjects and a Speciality Module, where students can elect engineering subjects, taught in their field of engineering at Tallinn University of Technology.

Table 1. Structure of the Curriculum.

MODULE	ECTS credits
MODULES OF ENGINEERING PEDAGOGY	
Compulsory Subjects	
Engineering Pedagogy Core and Basic Module	
Engineering Pedagogy in Theory and Practice	6
Laboratory Didactics and Methodology	3
Engineering Pedagogy Theoretical Module	
Psychological and Sociological Aspects	3
Ethical Aspects and Intercultural Competencies	2
Engineering Pedagogy Practical Module	
Rhetoric and Communication	3
Understandable Text Creation, Scientific Writing	3
Working with Projects: Curricula	3
Media (Teaching Technology) and E-Learning	3
SPECIALITY MODULE	
Elective Module	
Elective Engineering Speciality Subjects according to specialisation in engineering education	9
Total	35

Curriculum for continuing education of engineering educators has been prepared taking account of the most popular and perspective branches of industry in Estonia. Eight possible specializations have been proposed:

1. Civil Engineering;
2. Power Engineering;
3. Geological Technology;
4. Information and Communication Technology;
5. Chemical Engineering and Material Technology (including Wood Processing, Food Engineering, Textile and Garment Engineering);
6. Logistics;
7. Mechanical Engineering;
8. Technical Physics.

The interdisciplinary scope of the curriculum cannot be squeezed into one conventional university department. As there are 8 possible specialisations, corresponding engineering faculties of Tallinn University of Technology are all involved in the curriculum. Studies in Engineering Pedagogy have been planned and designed taking account of the main aspects of Klagenfurt School of Engineering Pedagogy (Austria). 23 professors of Tallinn University of Technology have passed the relevant international courses at Estonian Centre for Engineering Pedagogy and have been awarded the title of International Engineering Educator.

Education is completed by passing the final examination. During the examination the candidates must show that they have acquired the skills of an engineering educator. The final examination consists of the presentation and discussion of the candidate's portfolio and an examination interview. The portfolio contains confirmations that the candidate has completed the studies in all the modules, the complete written planning and performance of a teaching session, including video recording, and a subsequent analysis as well as the problem solving of at least one didactic case study. Students who have fulfilled the curriculum and passed the final examination are awarded a certificate of an engineering educator, and may apply for a qualification of an international engineering educator from International Society for Engineering Education IGIP (www.igip.org).

Discussion

Norbert Kraker (Kraker, 2005) has pointed out that the 'Circle of Engineering Pedagogy' is a quintet of five disciplines which help to develop engineering educators' competencies. The five components of the circle are applied sciences (e.g. mechanical engineering, electrical engineering, software engineering, etc), social sciences (pedagogical psychology, pedagogical sociology), subject-related didactics (didactics of teaching theoretical subjects, didactics of teaching in the laboratory, didactics of blended learning), supervised teaching practice (in the different learning environments) as well as additional courses (communication skills, a foreign language as a medium of instruction, administration, quality management, project work). Presented 'Circle of Engineering Pedagogy' has served as the basis of the proposed curriculum.

It is expected that the graduate of a programme, in addition to a high degree of engineering expertise, can also demonstrate solid competence in Engineering Pedagogy Science in Theory and Practice, being the spine of the curriculum, where the starting point is practically oriented technical teaching of engineering subjects. In the sense of a theory and practice composite, all the modules of the curriculum are grouped around this core module in the context of communicative interactive system. All the modules of the curriculum are integrated and summarised at this point.

The education should start with the subject of Engineering Pedagogy in Theory and Practice. At the outset, this gives the target group a structural overview and introduction. Over the course of the programme, the remaining material should be integrated into the training schedule and, at the end of the training programme, should also be planned to provide a final summary. The focus of the exercises is the development of lesson plans with themes from technical subjects and presentation of lessons. The exercises must be planned in detail in written form and be practised with the group. In every case, they should be recorded and analysed using the video recordings. Students also act in this context as a review panel. The subject develop the core competencies for planning, performing and evaluating teaching and learning events of all kinds in the disciplines of natural sciences and engineering for the fields of higher and continuing education, providing theoretical basis in the sense of knowledge, a repertoire of teaching methods, and value orientation in teaching – the ability to perceive students individually as partners in learning, in relationships marked by mutual respect and to motivate and guide them towards research-oriented learning, and reflect one's own teaching. The practical part of the subject Engineering Pedagogy trains the practical basics for competences as an engineering educator.

In terms of focal points, the subject of Laboratory Didactics and Methodology deals with psychomotoric aspects of technical teaching, experimental technical projects and research, requiring the previous knowledge of and intensive working with the contents of the subject Engineering Pedagogy Science in Theory and Practice. The subject reinforces in particular social, organisational, communicative, ethical skills and enables the students to plan and develop laboratory exercises reflecting the schedule of courses and pay attention to the different learning levels as well as team and communication competencies, write didactically structured laboratory manuals, and plan the use of computers in the laboratory.

In the subject of Psychological and Sociological Aspects an in-depth understanding of teaching and learning should be worked out, especially topics related to cognitive psychology as well as educational psychology should be examined. The purpose of this subject is also to sketch out the methodological approach to sociology. On particular, this should be presented using the example of how social groups function and their characteristic dependencies. The students acquire theoretical and practical fundamentals in social and communication psychology, in learning and developmental psychology and in pedagogical psychology. They acquire deep understanding of teaching and learning, experience and understand learning as a part of the interaction between teachers and learners.

The study of Rhetoric and Communication should lead to an increased awareness of how language is used and provide at least a superficial demonstration of the problematic of voice training, the right articulation from a basic degree of clarity to fascinating persuasive power. The actual communication and discussion training is intended to improve language use both in teaching situations and in situations involving decisions amongst colleagues. The communicative competences are essential for working successfully as a teacher. The students master the monologue and dialogue forms of communication, acquire skills of clear and understandable wording, argue persuasively, master feedback rules and questioning techniques, and learn to use them.

The objective of the subject Understandable Text Creation, Scientific Writing – starting from the theoretical basis – is close-to-practice training for independent composition of easily understandable texts in the fields of technology and the natural sciences. The students are familiar with text types and their characteristic in science and technology, learn didactic conception of scientific and engineering texts (script, formulas, etc), master writing understandably for target audiences, structure texts clearly, and create convincing graphics, illustrations and presentations.

The subject of Working with Projects: Curricula is a form of learning which is especially suitable for connecting the application of and immersion into specialised scientific contents with a subject-oriented personality development. The subject requires knowledge learned in the core subject Engineering Pedagogy Science in Theory and Practice and also Psychological and Sociological Aspects. The students can have a conscious feel for simultaneous connection of competence in the subject, method and social competences in the form of learning.

The subject Ethics and Intercultural aspects is intended to present basic positions in ethics, attention being devoted especially to ethics in the fields of science and technology. The subject deals with the development characteristics peculiar to people, psychologically sets limits of human endurance, with the problematic of the intercultural problems in courses.

The subject Media (Teaching Technology) and E-Learning focuses on the most important devices, facilities and systems contributing to the design of classroom teaching. Attention is devoted to the function, operation, but especially the appropriate use of the contemporary devices. The students master the use of basic types of media-supported teaching forms of media-supported individual learning, synchronous and asynchronous e-learning techniques and learning platforms, the appropriate use of CAD, CAM and CAE in teaching: animation, simulation and their limits.

We recommend implementation of the focal points of the knowledge and competences learned in the individual subjects directly in teaching practice during the short teaching trials of engineering pedagogy practice which should take place immediately afterwards. At this time the lecturer of the subjects should be included in the evaluation and thoughtful analysis of the teaching trials.

The students should document on a continuous basis the learning processes and work results subject by subject in a portfolio that should contain the confirmation of the lecturers of all subjects. The portfolio should also contain self-evaluation of the study process and a learning style of an individual student. Furthermore, the complete planning, performance and analysis of a course including video recording as well as the solution of a didactic case study should be presented for the final examination to Engineering Pedagogy Colloquium – both documented in the portfolio.

At Tallinn University of Technology there is also a registered and accredited Master programme for technical teachers in the amount of 60 ECTS credits. According to Estonian legislation, and especially to the Standard of Higher Education, regulating higher education, Master studies may be carried out either in the amount of 60 ECTS or 120 ECTS credits. Master courses in the amount of 60 ECTS credits are allowed if the admission requirement is already afore acquired Master degree. All the subjects listed in the newly designed curriculum for continuing education of engineering educators are also the subjects in the Master programme. It is possible to pass additionally the rest subjects of the Master programme in the amount of 25 ECTS credits subsequently later, accordingly to the life-long learning programme, after which the student will be awarded the MA degree in education. Thus life-long learning of engineering educators could be arranged.

Based upon the principle of 'continuous improvement,' the curriculum should be revised (with changes in teaching materials and tools and re-examination of the strategies used) based upon the quality of the learning experiences as determined through assessment and evaluation. This constant adaptation will require flexibility on the part of both - the educators and the administration.

According to the legislation of Tallinn University of Technology, Estonian Centre for Engineering Pedagogy has the right to make necessary changes to the curriculum in order to permanently improve and enhance the educational process.

Conclusion

Estonian Centre for Engineering Pedagogy at Tallinn University of Technology has been accredited by IGIP as Engineering Education Training Centre for International Engineering Educators in 2003 and reaccredited in 2008. The newly designed curriculum is the first one in Estonia that fulfils at same time the requirements of IGIP and the requirements of laws regulating teacher education in Estonia especially designed for continuing education for engineering educators. Everyone passing the curriculum can apply for the title of International Engineering Educator ING-PAED IGIP.

Possessing of relevant knowledge, creation of new knowledge and the capacity for its application have become the determinants of the strength of a nation. Consequently, engineering education has come to the centre stage and is today the most important agent for change and development. Quality of technical education depends on the quality of teaching. The quality of teaching in turn crucially depends on the quality of teachers. In order to improve the quality of technical education the foremost mission should be to improve the quality of engineering educators.

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