Curriculum Planning in Energy Engineering Education

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Abstract

Curriculum planning is a topical issue at Aalto University, as the new bachelor's and master's programmes will change the traditional structures of the programmes. In practice, the number of programmes will be reduced and the cooperation between different disciplines should become more intense. This renovation also provides an opportunity for curriculum centred strategic planning and re-design as well as development of teaching methods. However, such strategic planning has not been used at the Aalto School of Engineering or at the Department of Energy Technology under it. This work aims to explore practical and theoretical principles of curriculum-centred strategic planning, different teaching methods and aspects in integration of teaching and research. These topics will be considered in the development of energy engineering programme and focusing, in particular, in one of its six advanced modules "Urban Energy Engineering and Energy Economics". This module consists of four courses with two responsible professors and one teaching researcher. The aim here is to inspect how curriculum planning and its implementation are visible in the module. The research approach used in this paper includes a student survey, teacher interviews, and information about the core content analysis.

The student survey shows that students value education where they receive sector-specific expertise. On the other hand, students are interested in the latest scientific knowledge, environmental awareness, and life cycle based skills. Based on the student survey, the development actions of teaching should go towards to participatory processes of students and research-based teaching. Based on the teacher interviews, the development actions of education should involve systematic teaching planning processes and integration of research and teaching. General findings show that the continuous feedback and evaluation processes of the programmes would be needed in improving the overall alignment and quality of energy engineering education. Further development of curriculum planning will be discussed in this paper and results utilised in the development of the new energy engineering bachelor's and master's degree programmes in the following years.

1 Introduction

Curriculum is a key factor in university teaching. It manifests the university rules, the course contents, and defines the programme outcomes. Curriculum reform offers an opportunity to make desired changes to the degree programmes. The curriculum planning process seems to need time and cooperation of many stakeholders inside and outside of the university (Sng, 2008; Crawley et al., 2010). Many studies have pointed out lack of commitment of stakeholders and a need for better interaction between universities and working life (Dolence, 2004; Tynjälä et al., 2003). It is obvious that any university has a challenging task to improve continuously its curriculum, follow its mission and strategy, pass programme accreditations, fulfil needs of interested parties, be consistent with the

outcomes and objectives of its programmes, and harmonise its education along the Bologna process of the European Union (EU) (Sursock & Smidt, 2010; Hakula et al., 2013).

The authors inspect the course-level curriculum planning at the Department of Energy Technology. Their focus is on Master's level energy programme which includes five major subjects. The module "Urban Energy Engineering and Energy Economics" and its four courses are the main focus of this paper. The authors have set their primary goals on three different areas: to identify the coherence of curriculum planning at the module level, to identify applied teaching methods, and to increase student-centred learning practices inside the module. The overall goal of the authors is to identify best practices and compile recommendations for strategic planning and teaching of the energy degree programme. The research methods employed for this goal are: student survey, semi-structured teacher interviews, and the core content analysis (Auvinen, 2011). These methods obtain qualitative and quantitative information as well as in-depth understanding of teaching and learning practices in this module. The student survey provides quantitative data on learning issues before students attend the courses, while the interviews provide qualitative information on fundamentals of curriculum planning. The core content analysis brings information on the learning outcomes and workloads of the courses rated by the responsible teachers. This information sets the context for both the survey and interviews. After, curriculum planning process and best practices will be discussed in this paper on the basis of these results. The findings presented in this paper connect directly to the earlier work of the authors (Mälkki & Paatero 2012).

2 Background

Many researchers have focused on the strong connection between the curricula development and the learning objectives (Batterman et al., 2011; Biggs, 2004, Wong & Cheung, 2009). Curriculum typically consists of modules and courses that are linked together to produce the planned outcomes. When moving towards larger wholes, Dolence (2003, 2004) uses the term "strategic planning" to refer to the overall design process of curriculum, where each part of the plan is expected to be as part of a larger whole which is lasting a longer period and including all the teaching. He proposes that planning of teaching and research agendas should reflect new developments in existing fields and emerging areas of inquiry with closer links between related or complementary fields. He supposes that this would imply a more open approach to staff management, evaluation and funding criteria, teaching, curricula and research. On the other hand, Biggs (1996) has pointed out that enhancing teaching begins from defining the teaching objectives for the whole system. Adding to this, Levander & Mikkola (2009) have introduced curriculum as interconnected courses along the learning path including educational goals, content of education, working methods and learning outcomes. They define the learning outcomes as personal and interpersonal skills, and product, process and system building skills, as well as disciplinary knowledge, consistent with programme goals and validated by programme stakeholders. Also Crawley et al. (2010) present setting of learning outcomes as starting points of curriculum planning and adds examination of pre-existing conditions. These pre-existing conditions are reflecting national standards, university rules and programme traditions. Also the EUR-ACE accreditation process of the programme stresses the importance of programme outcomes and programme educational objectives, and adds consistent with the requirements of national legislation and management system (EUR-ACE, 2008).

Although the entire degree programme will be on the subject of a planning process in the development of curriculum, the practical actions will take place on the module and course level. Strategic efforts are needed in combining the objectives of the university and the entire programme, improving

systematically existing courses or planning new courses, taking into account the stakeholders' needs and ensuring students' skills for future career within the new programme. This seems to be a challenging task according to many studies. Biggs (2003) presents as a solution that the `Constructive alignment` approach is needed in combining all components in the teaching system to be aligned to each other. He lists the curriculum and its intended outcomes, the teaching methods used, and the assessment tasks as parts of the teaching system. Relevant learning activities support high level learning (Mälkki & Paatero, 2012) and Litzinger at al. (2011) believe that an integration of effective learning experiences could be increased in the systematic curriculum design process. For example, problem solving activities such as problem-based-learning (PBL) in the course content could develop learners´ understanding of subject matter and real-life situations (Loyens and Gijbels, 2008; Mälkki et al., 2012; Tynjälä et al., 2003). Effects of constructivist learning environments and knowledge building to promote learning are discussed by Loyens and Gijbels (2008). Students' formal and informal skills are formed through their studies when they are attending courses of the programme. Hence, individual courses play an important role in building knowledge and working life related competencies. For example, research-based teaching and student-centred learning are important strategies in improving desired employability skills for students in Aalto University´s strategy. Crawley et al. (2007), on the other hand, highlight a need to rethink engineering education in order to advance interdisciplinary understanding and proactive teaching and learning processes.

Various methods and tools are available in clarifying the contents of programmes and courses. Data and knowledge through these tools are essential in curriculum planning. Levander & Mikkola (2009) introduces a core curriculum analysis as a conceptual tool to analyse, describe, share and make comprehensible the degree programmes from the level of individual courses to the level of the whole programme. Aalto University has developed a computer aided core curriculum analysis tool to help curriculum planning efforts (Auvinen 2011). This tool forces the teachers to determine the learning outcomes of their courses and cooperate with the other teachers of the programme. External pressure for the use of core curriculum analysis arose from the Bologna Declaration and the Bologna process (Reinalda, 2008). The Bologna degree reform started in 2005 at Finnish technical universities with the inclusion of the bachelor´s degree before the master`s degree. This has implied a need for a strategic curriculum planning of the both bachelor´s and master`s degree programmes.

3 Case-study

At Aalto University a curriculum reform of Bachelor´s and Master´s degree programmes will affect the status and role of every course in the programmes. Some of the courses will be removed, whereas parts of their contents will be injected in other, more extensive courses. For this reason, it is important to clarify the status and content of the energy courses before the new energy major´s studies enter into force. To make the improvement of curriculum effective, the alignment of taught courses becomes important. To identify alignment in existing courses and to be able to plan the alignment in the new, reformed curriculum, comprehensive analysis of the taught courses is important. Here this has been done through analysis of the content and courses of the Aalto University module Urban Energy Systems and Energy Economics (UESEE, see Table 1) through a student survey, teacher interviews, and core content analysis.

The UESEE module aims to provide students a basic understanding about the energy technologies applied in the urban environment and urban energy infrastructure, urban planning and its connections to urban energy planning, energy investments, energy markets, district heating engineering, and energy system models optimization at different levels.

Table 1. Urban Energy Systems and Energy Economics (UESEE) teaching module.

Minor in Energy Systems for Communities and Energy Economics, Module I (20 cr)	ECTS Course Points
Models and Optimization of Energy Systems	5
District Heating Engineering	5
Energy Markets	5
Energy Systems for Communities	5

The core curriculum analysis of the UESEE courses was done using their pre-existing curriculum planning documents in summer 2012. Much of these documents have been prepared for the 2009 re-audit of Aalto University (then Helsinki University of Technology) by the Finnish Higher Education Evaluation Council (Karppanen et al., 2010) and the 2010-2011 Aalto University Teaching and Education Evaluation process (TEE, 2011). Although most of these documents have been prepared with a 'core curriculum analysis' mind-set, their quality and level of detail varied significantly between the UESEE courses. Particularly the level of detail on learning goals had major differences.

Table 2: Key questions in the questionnaire about student skills, preferences, and expectations.

No	COMPETENCIES: Please indicate your current skill level with the following competences and which of them you expect(ed) and/or would like to improve through attending the set of courses in module you are planning to attend or have attended.	KNOWLEDGE: Please indicate the level of knowledge you would like to be taught in the set of courses in module you are planning to attend or have attended.
01	Basic natural sciences and mathematics	Conventional energy technologies
02	Analytical skills	Renewable energy technologies
03	Problem-solving skills	Modelling of energy systems
04	Critical thinking	District heating systems
05	Applying theoretical knowledge into practice	Cost accounting and investment analysis
06	Latest research knowledge	Economics
07	Creativity	Global energy markets (like oil, coal, natural gas)
08	Basics skills in entrepreneurship	Nordic electricity market
09	Project management	Energy policy
10	Leadership skills	Energy and greenhouse gases
11	Group work	Energy and sustainability
12	Social skills	Energy and urban planning
13	Dealing with international environments	Innovations in energy technology
14	Information retrieval skills	
15	Presentation, speaking and negotiation skills	
16	Skills with your best foreign language	
17	Writing skills	
18	Life-long learning skills	
19	Self-knowledge	
20	Ethical awareness	
21	Environmental awareness	
22	Sustainability awareness	
23	Life-cycle assessment skills	

The student survey was conducted in a~~A~~utumn 2012 on the typical starting course of the UESEE module including altogether 61 respondents. After student profiling, the survey asked the students' perceptions of their knowledge and skill levels before the course. Students were first asked to evaluate a selected set of their current professional skills and then to reveal their expectations on improvements of the skills while passing the module. In addition, students were asked about preferred teaching methods and expectations about learning topical knowledge. Knowledge and skill levels were asked about in four-step scale: 1 = "nothing", 2 = "basic level", 3 = "intermediate level" and 4 = "expert level ". A comprehensive list of the questions in the questionnaire and the alternative student answers have been provided in Table 2.

The interviews were conducted to two of the three teachers of the UESEE module based on state of their courses in summer 2012. They were performed in a semi-structured form, using an indicative list

of 13 main themes and questions to support the interviewer. The teachers were asked about several aspects of course and curriculum planning practices in the module, including goal setting, division of responsibility, levels of collaboration, use of feedback, and documentation.

4 Results of the core content analysis, student surveys, and teacher interviews

The core content analysis of the UESEE courses provided a valuable background and context for the applied student survey and teacher interviews. It revealed the ways the content was interconnected. Due to the wide scope the four courses in the module mainly connect horizontally, not building on the content taught of each other. The only exception is the course "Models and Optimization of Energy Systems," where the knowledge from the course "Energy Markets" is required. Thus there is very limited possibility to build on the knowledge and experience of students from the other courses within the module. The analysis also revealed that the learning goals of courses were mainly defined through core engineering skills, mathematical skills, and analytical skills. There was very limited content and goals concerning informal skills like team work and presentation skills.

The results of the student survey provided deeper understanding about how the participants perceive themselves and the education they are receiving. The background of the participating students was divided: 57% of them were in Finnish degree programmes, 64% were doing their master's degree and 61% were studying full-time. The rest mostly did bachelor's degrees, had English degree programmes and worked 25-50% of the time. However, they do represent quite a typical set of students taking the UESEE courses.

As students were asked to identify their own level in a selected list of skills, they expressed the highest competence in 'basic natural sciences and mathematics' and 'critical thinking' followed by 'social skills', 'group work', 'problem solving skills', 'self-knowledge', and 'writing skills'. The lowest competence by far was expressed in 'latest research knowledge' and 'basics skills in entrepreneurship'. Some other low-hitting skills were 'life-cycle assessment skills', 'project management', and 'leadership skills'. In the two highest ranked skills more than 75% of the students identified their skill level as intermediate or expert level. Correspondingly, in the two lowest hitting skills more than 65% of the students identified their skill level as none or basic.

When asked what competences the students expect or would like to be improved through attending the UESEE courses, over 59% of them pointed out 'environmental awareness' and 'sustainability awareness'. The next most popular topics were 'critical thinking', 'latest research knowledge', and 'life-cycle assessment skills'. The skills with lowest interest and expectations were 'self-knowledge', 'basic natural sciences and mathematics', 'writing skills', and 'social skills'. While most of the low interest skills were in the high-end of the evaluation of own skills, 'critical thinking' received high interest even if it was the skill with second highest student self-evaluation skill level to start with.

In their preferences for course teaching and evaluation methods the students showed a strong correlation (0.75) between their earlier experiences with the methods and how much they wanted it to be used. The methods widely applied during the earlier part of their studies (lecturing, exercises) were highly popular (>63%) while unfamiliar and little used approaches (like reading circle and lecture diaries) received very low approval rates (>16%). Clear exceptions were field trips that were very popular (62%) even if only 46% had experience of them. In addition, the very commonly used exams and home assignments received relatively low popularity (36% and 38%). Essay writing was not as common (43%) and received very low popularity (11%).

Concerning the level of knowledge students would like to be taught in the UESEE courses, the results show a clear spread. Clearly highest popularity was given to 'renewable energy technologies' with 90% of the students wanting 'advanced' or 'expert' level of knowledge to be taught. Following near at 80% are 'global energy markets' and 'innovations in energy technology'. Correspondingly, lowest interest was expressed to 'district heating systems' with 46% of the students wanting 'none' or 'basic' level of knowledge to be taught.

The interviews of teachers provided information about how the interviewed staff perceives and implements the education services they provide. In practice the results deal with planning of the courses, and applied teaching and evaluation methods.

The interviews revealed that the content of UESEE courses has been selected based on both teaching needs in the module and curriculum and interests of the responsible staff. The choices may in some cases also have been influenced by the already existing teaching support materials. The applied teaching and evaluation methods composed mainly of traditionally used university teaching methods like lecturing, examinations, home assignments, and exercise session. Innovative or novel teaching approaches were occasionally tested, but not in any kind of systematic manner.

The interviews also showed~~,~~ that the applied course planning process has not been very systematic and that joint planning between teachers has been occurring rather randomly and not consistently. Course feedback was collected systematically through the student study planning platform and also through direct contact typically initiated by the students. The use of course feedback was very much up to the teacher and there was no systematized manner to deal with it. There was no other consistent source of teaching feedback in use in addition to the feedback from students.

5 Best practices for further development actions of curriculum planning and teaching

Teaching should be managed and developed in accordance with the university strategy. Strategic curriculum planning should involve the overall alignment of teaching and learning practices along the entire degree programme. Special attention should be paid to specifying learning outcomes. Teachers have to use teaching methods that suit the subject taught and support different types of learners to ensure participatory processes of students and student-centred in-depth learning. Contents and processes of teaching should react to the changes~~ing~~ needed in~~s of~~ working life, society and science~~. as required.~~ The quality of educational processes has to be revised through student feedback as well as surveys and discussions focused on those in working life.

On the module-level the alignment with degree programme and within the module could be best achieved through close collaboration of the teaching staff in planning the learning outcomes, teaching, and assessment methods applied in the module. It should also be considered that students are relatively conservative and should have proper introduction to novel teaching methods in the early years of their studies. This makes it more flexible to teach the students informal skills in the later parts of their studies.

The students are very interested in expert knowledge on their field and the curriculum should include knowledge about the latest research discoveries. It should also be noted that students have high interest on environmental and sustainability issues. It is thus recommended that such content is supplemented to the core contents of the course.

6 Conclusions and discussions

The contents and structures of teaching should be renewed and developed continuously in close cooperation with the entire university community. Curriculum planning normally begins with the learning outcomes for the entire degree programme, modules and courses. Defining of learning outcomes requires efforts and commitment among stakeholders at the various levels of university community, and working life. Systematic teaching planning processes, participatory processes of students, research-based teaching and integration of research and teaching are essential parts of alignment efforts within the entire degree programme.

Findings of this paper support the idea that the best way to adopt changes of teaching and learning practices in curriculum is to proceed enough slowly towards participatory processes of students. The curriculum reform, especially when embedding student-centred learning practices would improve students´ employability skills and working life competencies after their graduation. However, students seem to be rather conservative to new teaching and learning practices. Hence, further studies could focus on causes and background factors of students' preferences. Analysis of these results could improve curriculum planning and implement desired educational changes more effectively within the courses and the entire degree programme.

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