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Curriculum Planning in Energy Engineering Education

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Abstract

Curriculum is a key factor in defining programme outcomes. It typically consists of modules and courses, which should be linked together to produce the desired learning outcomes for students. This work aims to explore practical and theoretical principles of curriculum-centred strategic planning and to inspect how curriculum planning and its implementation are visible in the corresponding teaching structures and student experiences. The research approach used in this paper includes a student survey, teacher interviews and core content analysis. The paper demonstrates that when addressing only a cluster of courses, a relatively simplified approach provides sufficient information for identifying existing strengths and good practices that can be built on as well as key areas that need further improvement. In addition, the key observations and best practices can also be utilized at any engineering education context. The material utilized in this paper has been obtained from the 'Urban Energy Engineering and Energy Economics' module of Aalto University's Energy Engineering Degree Programme.

Keywords: energy engineering education, curriculum planning, student perspectives, best practices, Aalto University

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1 Introduction

Curriculum is a key factor in university teaching. It reflects the university's rules and course content and it defines programme outcomes. Curriculum reform offers an opportunity to make desired changes to the degree programmes. A successful curriculum planning process seems to take time and cooperation between many stakeholders both inside and outside of the university (Gunnarsson, S., 2010; Desha and Hargroves, 2010; Sng, 2008). Many authors have called attention to the need for better interaction between universities and those involved in working life in order to provide industry-relevant competencies (Jackson, 2010; Tynjälä et al., 2003). In connection with successful curriculum planning, a university needs to simultaneously follow its mission and strategy, pass programme quality accreditations, meet the needs of interested parties, be consistent with respect to the outcomes and objectives of its programmes, and, in the European Union (EU), harmonise its education so that it conforms to the Bologna Process directives (Dolence, 2004; Hakula et al., 2013; Sursock and Smidt, 2010).

This paper discusses course-level curriculum planning at Aalto University's Department of Energy Technology. It focuses on a Master's level energy programme that includes five major subjects. In particular, it focuses on the Urban Energy Systems and Energy Economics (UESEE) module and the four courses comprising it. The authors have three primary goals: to identify the coherence of curriculum planning at the module level, to identify applied teaching methods and to increase student-centred learning practices within the module. Their overall goal is to identify best practices and compile recommendations for strategic planning and teaching in the energy engineering degree programme. These best practices and recommendations can be utilised within any engineering education context.

The research methods employed to achieve this goal are as follows: a student survey, semi-structured teacher interviews and core content analysis (Lindblom-Ylänne and Hämäläinen, 2004). These methods are employed to obtain an in-depth understanding of the pedagogical approaches applied in the teaching and evaluation of the courses that are a part of the module. Afterwards, the paper will discuss the curriculum planning process and best practices based on these results. To limit the scope of this paper, the authors have not included any interviews with representatives of working life. The findings presented in this paper are based on earlier, preparatory work done by the authors (Mälkki and Paatero, 2012, 2013). However, this paper is based on a broader set of data and presents more thorough observations and findings.

2 Background

Many researchers have focused on the strong connection between curricula development and learning outcomes (Batterman et al., 2011; Biggs and Tang, 2007; Wong and Cheung, 2009). Curriculum typically consists of modules and courses that are linked together to produce the desired outcomes. When moving towards larger wholes, Dolence (2003, 2004) uses the term ‘strategic planning’ to refer to the overall design process for curriculum, where each part of the plan is expected to be part of a larger whole that lasts for a longer period of time and includes all of the teaching done as part of the module. He proposes that the 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 believes that this would entail a more open approach to staff management, evaluation and funding criteria, teaching, curricula and research.

Exploring the issue further, Biggs (1996) has pointed out that the process of enhancing teaching includes teaching and learning activities that achieve the curriculum objectives for the whole system. Adding to this, Levander and Mikkola (2009) have introduced the idea that curriculum consists of interconnected courses along the learning path; as such, curriculum should include educational goals, educational content, working methods and learning outcomes. Furthermore, Edström et al. (2010) have suggested that learning outcomes are the foundation for curriculum planning. The planning process begins by reflecting on the pre-existing learning environment and then identifying the desired changes and outcomes. In a similar manner, strategic curriculum planning reflects national accreditation standards, university rules and programme traditions.

Biggs (2003) argues that a ‘constructive alignment’ approach is needed to combine all components of the teaching system so that they are properly aligned with one another. He lists curriculum and its intended outcomes, teaching methods and assessment tasks as parts of the teaching system that need to be aligned with learning activities. Segalàs et al. (2010) experimentally verified that students’ learning outcomes could be enhanced by community-oriented and constructive learning approaches. Such learning activities could support high-level learning (Mälkki and Paatero, 2012); likewise, Litzinger et al. (2011) believe that effective learning experiences could be better integrated within the systematic curriculum design process. For example, including problem-solving activities, such as problem-based learning (PBL), in the course content could develop learners’ understanding of the subject matter and real-life situations (Loyens and Gijbels, 2008; Mälkki et al., 2012; Tynjälä et al., 2003). Additionally, Lansu et al. (2013) have highlighted the need to rethink engineering education as a means of including the professional demands of stakeholders and academic quality standards in the process of curriculum planning.

The ways in which constructivist learning environments and knowledge building promote learning have also been discussed by Loyens and Gijbels (2008). Students' formal and informal skills are formed during their studies when they are attending courses that are a part of the programme. Hence, individual courses play an important role in building knowledge and working life-related competencies.

Levander and Mikkola (2009) have proposed the idea of using core curriculum analysis as a conceptual tool for analysing, describing, sharing and making the degree programmes understandable at the level of individual courses as well as at the level of the whole programme. Aalto University has been developing a computer-aided core curriculum analysis tool to help curriculum planning efforts (Auvinen, 2011). This tool will help teachers determine the learning outcomes for their courses and cooperate with other teachers in the programme.

In addition to core curriculum analysis, student feedback has been utilised when developing curriculum at Aalto University. Since late 2009, it has been mandatory for teachers to collect feedback; the process is automated, whereby students are asked to provide feedback using the same software platform they use for their individual curriculum plans. Mainly quantitative feedback data are collected using standardised or for the most part standardised forms at the end of each course. The forms also have a field for general remarks and opinions, resulting in qualitative feedback data. Richardson (2005) has explored the questionnaires used in North American, Australian and British studies, and he noticed that there is a clear need to collect more student feedback that can be used as research evidence about teaching, learning and assessment. The research-based results provided by such feedback can be used to improve teaching quality, but he warns that it is unlikely that simply collecting the feedback will lead to significant improvements.

The Bologna Process added external pressure to the need for European universities to use learning outcomes as a basis for establishing national qualification frameworks and arrangements for recognising prior learning (Reinalda, 2008; Rauhvargers et al., 2009). The outcomes and educational objectives of a particular programme are also stressed in the EUR-ACE accreditation process. The accreditation process includes the requirements specified in national legislation and by the university-level management system (EUR-ACE, 2008).

The degree reforms prompted by the Bologna Process began in 2005 and resulted in Finnish technical universities adopting a two-level educational system consisting of both a Bachelor´s degree and a Master´s degree. As a result, energy engineering was divided into two separate and independent parts: namely, the Bachelor´s degree and Master´s degree programmes. In addition, students now need to complete the Bachelor´s level degree before beginning Master´s level studies. The first wave of changes in the degree was implemented immediately after the Bologna reform; however, the reforms included mainly reorganising courses and only a limited number of revisions to courses or actual re-planning of courses. The current, more fundamental change includes a full re-evaluation of all of the teaching and course contents. This has implied a need for strategic curriculum planning for both Bachelor´s level and Master´s degree programmes. The ongoing curriculum reform of the Bachelor´s and Master´s degree programmes affects the status and role of every course in all of the programmes at Aalto University. Major changes are being made to previously existing courses and curriculum structures. Some of the courses will be discontinued and their content introduced to other, more comprehensive courses. For this reason, it is important to clarify the status and content of the energy courses before the new Master’s level degree programme in energy engineering enters into force. To effectively improve the curriculum, it will be necessary to provide a comprehensive analysis of the courses being taught when aligning the existing courses and planning the new reformed curriculum (Eskandari et al., 2007).

In 2012, Aalto University’s Master’s degree programme in energy engineering (120 ECTS) included 3–4 teaching modules (20 ECTS each), with each module consisting of 3–7 courses. In addition, the programme included 40–60 ECTS of other coursework, including a Master’s thesis (30 ECTS). The programme has a total of five specialisation options (major subjects), including Urban Energy Systems and Energy Economics (UESEE).

3 Research methods

To understand and document the current teaching and course planning practices that are a part of Aalto University’s energy engineering education, it was important to focus on a module that serves a large number of energy engineering students. In addition, when the curriculum reform of the Bachelor´s and Master´s degree programmes was at its initial stages, the Master’s level modules were the most relevant area for pedagogical inquiry. For the Master’s degree programme in energy engineering, Urban Energy Systems and Energy Economics (UESEE) is the most popular subject. In addition, the first Master’s level module that the students specialising in UESEE take carries the same name as the major (Urban Energy Systems and Energy Economics, see Table 1).

The UESEE teaching module aims to provide students with a basic understanding of the types of energy technologies applied in an urban environment and of the urban energy infrastructure and urban planning and the ways in which they are connected to urban energy planning, energy investments, energy markets, district heating engineering and energy system models that are optimised at different levels. To analyse the content and teaching in the cluster of courses forming the UESEE module, an approach using three different methods and angles was utilised. The three selected methods consisted of a student survey, teacher interviews and core content analysis; the methods correspondingly shed light on student-centred, teacher-centred and curriculum planning views on the matter.

These methods yielded qualitative and quantitative information and also provided an in-depth understanding of the teaching and learning practices that are a part of this module. The student survey provided quantitative data on learning issues before students attend the courses, while the interviews provided qualitative information on the fundamentals of curriculum planning. The core content analysis yielded information on how the teachers rate the learning outcomes and workloads for the courses. This information established the general context for both the survey and interviews.

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

(Insert Table 1 around here)

The core curriculum analysis for the UESEE courses was done using pre-existing curriculum planning documents from the summer of 2012. Many of these documents had been prepared for the 2009 re-audit of Aalto University (then Helsinki University of Technology) conducted by the Finnish Higher Education Evaluation Council (Karppanen et al., 2010) and the 2010–2011 Aalto University Teaching and Education Evaluation process (Levander and Koivisto, 2011). Also, part of this material has been produced using a computer-aided tool developed by Auvinen (2011). Although most of these documents were prepared with a ‘core curriculum analysis’ mind set, their quality and level of detail varied significantly between the different UESEE courses. In particular, there were major differences in the level of detail with respect to the learning goals.

The aim of the student survey was to obtain a representative sample of the students who are taking the UESEE module. Thus, the sample was collected from two simultaneously ongoing courses at the beginning of autumn 2012. In this way, the sample included a large part of the overall student population and the individual surveys had only a minimal effect on the student population during the survey period. Some students were taking both of the courses where the surveys were conducted and they were requested to answer the survey only once.

To obtain a high participation rate, the surveys were conducted at the beginning of the first lectures for the courses, where more than 90% of the students taking the courses that year were present. All (100%) of the students at the two lectures responded to the survey, resulting in 88 respondents, which comprises a good representative sample.

After establishing student profiles, the survey asked students about their perceptions of the specific knowledge and working-life competences pertaining to their personal UESEE module before the course began. The students were first asked to evaluate a select set of their current working-life competences and then to reveal their expectations about improving the competences while completing the module. In addition, students were asked about their preferred teaching methods and expectations about learning information specific to the UESEE module. Students were asked to rate their knowledge and competence levels using a four-point scale: 1 = ‘nothing’, 2 =

‘basic level’, 3 = ‘intermediate level’ and 4 = ‘expert level’. A comprehensive list of the competencies and knowledge used in the questionnaire is provided in Table 2.

Table 2. List of working-life competencies and knowledge specific to the UESEE module used in the student questionnaire.

(Insert Table 2 around here)

The interviews were designed to provide in-depth qualitative data about the course planning and implementation process that are part of the UESEE module. The courses in the module were managed by three teachers, while only two of them were available for interviews. However, one of the interviewed teachers was the person responsible for developing the courses in the UESEE module.

The interviews were conducted in the summer of 2012 and they focused on the courses currently being taught. They were conducted in a semi-structured format, using an indicative list of 13 main themes and questions to support the interviewer. The teachers were interviewed separately and asked about several aspects of the course and curriculum planning practices in the module, including goal setting, sharing of responsibility, levels of collaboration, use of feedback and documentation. Due to the small number of interviews, no formal method was applied in the analysis of the material. Instead, conclusions were made through reflective discussions by the authors.

4 Results

The core content analysis of the UESEE courses provided the background and context for the applied student survey and teacher interviews. It revealed the ways in which the content being taught were interconnected and thus highlighted whether or not the principles of curriculum planning were present in the content being taught. Partly due to the broad scope of the courses, the four courses are mainly independent and only connected to one another in a parallel manner. The courses do not build on one another; instead, they all focus on their own areas of energy engineering, which are not directly connected to the other courses within the module. The only exception is the course 'Models and Optimization of Energy Systems', where prior knowledge from the 'Energy Markets' course is required. Thus, there is only a limited possibility to build on the knowledge and experiences that students have acquired from the other courses within the module. The analysis also revealed that the learning goals of the courses were mainly defined in the form of core engineering skills, mathematical skills and analytical skills. There was very limited content and few goals concerning informal skills, such as teamwork and presentation skills. Overall, the analysis showed that while the teaching of engineering skills, mathematical skills and analytical skills was clearly planned for in the curriculum, most of the skills connected to 'professional identity' (e.g. leadership, presentation skills, social skills) were overlooked in the curriculum planning and alignment process.

The interviews with the teachers provided information about how the staff in general perceive of and implement the education services they provide. In practice, the results deal with the planning of courses and with applied teaching and evaluation methods. The interviews were also crucial for inspecting how curriculum planning and its implementation are manifested in the UESEE courses.

The interviews revealed that the content of the UESEE courses has been selected based on both the teaching needs specified in the module and curriculum and the interests of the responsible staff. At times, the choices have also been influenced by the already existing support materials for the course. Overall, we discovered that course planning has been influenced by curriculum-level teaching needs. However, the curriculum-level objectives have not been specified in detail and much freedom has been left to the teachers in terms of designing the contents of the courses and determining how the courses should be taught. In addition, the teaching and evaluation methods applied to the courses consisted mainly of traditional university teaching methods, such as lecturing, examinations, take-home assignments and exercise sessions. Innovative or novel teaching approaches were occasionally tested, but not in any kind of systematic manner.

The interviews also revealed that the planning process applied to individual courses has not been very systematic and that joint planning between teachers has only occurred on a rather random and inconsistent basis. Course feedback was collected systematically through the study planning software platform and also through direct contacts, typically initiated by the students. However, the use of course feedback was very much up to the teacher and there was no systematised manner for dealing with it. There was no other consistent source of feedback on the teaching content.

The results of the student survey provided a deeper understanding of how the students as participants perceive of themselves and the education they are receiving. Their professional identity and expertise can be viewed in terms of how the curriculum is planned and implemented. Their opinions thus provide a ‘customer’ viewpoint on the teaching process and its content. The results of the survey show that students have clearly distinguishable and consistent opinions about both the methods and the content of the education they are receiving. Thus, their voices should be considered when course content and applied teaching methods are being developed.

The background of the participating students was mixed: 63% of them were in Finnish degree programmes, 60% were completing a Master’s degree and 63% were studying full time. The rest were mostly enrolled in Bachelor’s degree programmes and

English degree programmes and worked 25% of the time. However, they do represent a typical set of students taking the UESEE courses.

In the questionnaire, the students were asked to identify their own level of competencies (see Table 2). The results are presented in Figure 1, which also includes the mean values for each category calculated based on the applied four-point scale. Based on the mean values, the students expressed the highest degree of competence in ‘basic natural sciences and mathematics’, ‘critical thinking’, ‘social skills’ and ‘skills with your best foreign language’, followed closely by ‘group work’, ‘problem-solving skills’ and ‘writing skills’. They expressed the lowest degree of competence by far in ‘latest research knowledge’ and ‘basics skills in entrepreneurship’. Some other low-hitting skills included ‘project management’, ‘life-cycle assessment skills’ and ‘leadership skills’. Of the two highest ranked skills, more than 70% of the students identified their skill level as being at the intermediate or expert level. Correspondingly, with respect to the two lowest ranking skills, more than 67% of the students identified their skill level as non-existent or basic.

(Insert Figure 1 around here)

Figure 1. Student estimates of their own level of competencies before the UESEE courses.

When asked what competences the students expect to acquire or would like to improve through attending the UESEE courses, almost 58% of them mentioned ‘environmental awareness’ and ‘sustainability awareness’, as seen in Figure 2. The next most popular topics in ascending order were ‘applying theoretical knowledge in practice’, ‘critical thinking’, ‘latest research knowledge’ and ‘life-cycle assessment skills’. The skills receiving the lowest level of interest and expectations were ‘self-knowledge’, ‘basic natural sciences and mathematics’, ‘writing skills’, ‘leadership skills’, life-long learning skills’ and ‘social skills’. While most of the low-interest skills mentioned by students were at the high end in terms of how they evaluated their own skills, ‘critical thinking’ received a high level of interest even though students also rated it as one of the skills they were already most competent in. In addition, students had low ‘leadership skills’ but also relatively little interest in improving such skills.

(Insert Figure 2 around here)

Figure 2. Percentage of students expecting to acquire or wanting to improve the listed competences through attending the UESEE courses.

In their preferences for course teaching and evaluation methods, presented in Figure 3, the students showed a strong correlation (0.77) between their earlier experiences with the methods and how much they wanted the same methods to be used in the future. The methods widely applied during the earlier part of their studies (lecturing, exercises) received a significant level of support (> 64% want it to be used), while unfamiliar and little-used approaches (like reading circles and keeping lecture diaries) received low approval ratings (< 12%). Clear exceptions were field trips, which students expressed a great deal of interest in (59%), even if only 38% had ever been on one. In addition, commonly used exams (68%) and take-home assignments (53%) were not particularly popular with students (with 40% and 41% of students wanting them to be used, respectively). While essay writing is also commonly used in courses (35%), the students expressed a strong level of disapproval for it as a teaching method: only 13% wanted it to be used as a teaching method.

(Insert Figure 3 around here)

Figure 3. Percentage of teaching and evaluation methods that students have had earlier experience with and would like to see used in the UESEE courses.

Concerning the level of knowledge that students would like to be exposed to in the UESEE courses, the results (see Figure 4) show a clear spread. Clearly, ‘renewable energy technologies’ was the most popular knowledge category, with 86% of the students saying that they want this topic to be taught at an ‘advanced’ or ‘expert’ level. Following close behind, 73–75% of students reported that they want ‘innovations in energy technology’ and ‘global energy markets’ to be taught at more of an advanced level. Correspondingly, they expressed the least amount of interest in the categories ‘district heating systems’, ‘economics’ and ‘energy and greenhouse gases’, with 40–42% of the students wanting to be exposed to either ‘none’ or only a ‘basic’ level of knowledge on these topics.

(Insert Figure 4 around here)

Figure 4. Student preferences about the level of knowledge that they want to be exposed to in the UESEE module.

Overall, the core content analysis, teacher interviews and student surveys revealed both good practices and clear needs for improvement in connection with the UESEE module. Also, according to the Aalto Sustainability Report 2013 there are clear needs to intensify teaching and research on global warming, energy conservation and clean energy, and the sustainable use of natural resources (Aalto University, 2013). On this basis, the next section discusses a selection of the best practices.

5 Discussion and recommendations

Teaching should be managed and developed in accordance with the university's strategy, which aims to create high-quality learning environments that meet the needs of society and the workplace. Although the entire degree programme will be subject to a planning process when developing curriculum, the practical actions should take place at the module and course level. Strategic efforts are needed to combine the objectives of the university and those for the entire programme, while at the same time systematically improving existing courses or planning new courses, taking into account the needs of stakeholders and ensuring that students acquire the skills they will need for their future careers. Much prior research suggests that this will be a challenging task (Eskandari et al., 2007; Lozano and Lozano, 2014).

One approach to manage teaching with close connection to the strategy of the university is to utilise strategic curriculum planning (Dolence, 2004), which should involve the overall alignment of teaching and learning practices throughout the entire degree programme. However, special attention should be paid to specifying learning outcomes, which are the fundamental elements of core content analysis and curriculum planning (Edström et al., 2010). This approach could also be quite successful at Aalto University, since at least the Department Energy Technology staff already has experience with core content analysis (Auvinen, 2011; Levander and Koivisto, 2011). Thus the authors strongly recommend the use of strategic curriculum planning at Aalto University or any university where emphasis is wanted for overall alignment of teaching.

To construct student-centred learning environments, teachers should use teaching methods that are suited to the subject being taught and support different types of learners so as to ensure the participation of more students (Biggs & Tang, 2007; Segalàs et al., 2010). The contents of the course and the teaching processes should respond to the changes needed in working life, society and science (Gunnarsson, S., 2010; Tynjälä et al., 2006). As a research-oriented university, Aalto University has a solid foundation in providing up-to-date, research-based educational content. This in-house expertise is quite attractive to students and could be utilised more widely. In addition, the ways in which the course content is connected to the changing needs of society and working life is left very much up to individual teachers. Thus, systematic and university-wide practices should be developed and implemented to also ensure up-to-date teaching in this area. As an example, Tynjälä et al. (2003) have suggested utilising organisational or critical dialogue to bring higher education closer to the needs of working life. The authors recommend introducing this or similar practice to Aalto University or any university where better connection to practitioners is sought after.

Aalto University, including the Department of Energy Technology, has a widespread practice of collecting student feedback, but it still depends very much on the teacher how this information is utilised. This information should be systematically utilised to revise educational processes, as student feedback provides valuable evidence about the quality of the educational activities in question (Richardson, 2005). As an example, the feedback could be discussed by an expert group after each course and the resulting observations could then be reported to the responsible manager and teacher of the course. The feedback information could also be complemented with surveys and discussions focused on current needs in terms of the regional development of working life (Jackson, 2010; Lansu et al., 2013). Overall, the authors strongly recommend Aalto

University to introduce a body, where student feedback will be systematically processed and utilised for curriculum development. Any university that lacks such body should consider its introduction as well.

Close collaboration within the university (e.g. by administrators, teachers, managers) is needed during every part of the curriculum planning process (Desha and Hargroves, 2010; Sng, 2008). This also applies to aligning the courses that are a part of the modules and the modules as a part of the degree programmes. Aalto University's Department of Energy Technology has previously allowed for the joint planning of courses and modules, but this has not been done in a systematic and consistent manner. However, there are clear signs that a more systematic approach to joint planning has been adopted in the ongoing reform of Bachelor's and Master's degree programmes. In addition, several members of the Department of Energy staff have taken part in the pedagogical education provided by Aalto University's Strategic Support for Research and Education (e.g. Hakula et al., 2013), where key skills for systematic curriculum and course planning can be learned. All of this shows the quite positive direction in which collaborative planning is headed, one that will result in well-aligned degree programmes. Thus the authors recommend that curriculum planning at Aalto University continues to build on such collaboration. However, special attention should be paid to introducing novel teaching methods, like problem-based learning, early on in the degree programmes so that the more conservative students will have time to adapt to these new methods.

Overall, special emphasis should be placed on the interest of students in environmental and sustainability issues. Even if there are specific programmes for these topics, energy engineering students still have a genuine interest in learning more about these themes. However, Lozano (2010) has pointed out that the successful integration of sustainability content also requires introducing balanced, synergistic, trans-disciplinary and holistic perspectives into the course content. It is thus recommended that such content, together with environmental and sustainability content, should be supplemented by the core content of the courses. This point should also be closely supported by the professional development of the staff of the Department of Energy Engineering. Barth and Rieckmann (2012) found that a staff development programme can result in more sustainability content being added to the curriculum. As a related teaching method, researchers recommend that student projects should include problem-based learning since such learning supports the integration of sustainability topics into the curriculum (Bacon et al., 2010). For a broader integration of sustainability issues, Ceulemans and De Prins (2010) recommend using a teacher`s manual to motivate and guide teachers in integrating sustainable development-related content within the curricula. The authors recommend Aalto University to adopt the use of such manual to ensure the integration of sustainability related contents to its curriculum. Similar practices are recommended for any university seeking to introduce sustainability content throughout its curriculum.

6 Conclusions

High-level university education should be based on a well-planned curriculum produced by the collaborative efforts of key stakeholders. One approach to curriculum reform is to use strategic curriculum planning, as discussed by Dolence (2003, 2004), one that takes into account the perspective of the larger whole and always considers the courses and modules as a part of whole degree programme. In addition, aligning the curriculum is a central component of strategic curriculum planning, one which begins with identifying the learning outcomes at the level of the degree programme, such as key working-life competences and knowledge related to the degree programme.

At Aalto University, the major reforms being implemented for degree programmes offered a natural basis for examining the existing practices and updating the learning outcomes. The interviews with the teachers about planning and teaching practices at Aalto University's Department of Energy Technology showed that the staff already has experience with some of the key practices of strategic curriculum planning. However, stronger emphasis is needed on maintaining an active connection to the needs of working life and promoting planning collaboration between teachers, at least at the Department of Energy Technology. One approach would be a department-wide adaptation of the organisational or critical dialogue, as suggested by Tynjälä et al. (2003), together with systematic and regular use of working groups consisting of members of the teaching staff and representatives of working life.

The results of the student survey indicate that special attention should also be given to their natural interests and tendencies. At the Department of Energy Technology, this includes, for example, taking into account student interest in applying theoretical knowledge in practice and acquiring up-to-date energy expertise and learning about sustainability issues. In addition, the students tended to reject teaching methods that they have limited experience with. Thus, any changes in teaching and learning practices need to be systematically planned and the use of alternative teaching approaches should proceed on a step-by-step basis within the curriculum. Hence, further studies could focus on the causes and background factors affecting the students' preferences. Analysis of these results could improve curriculum planning and the way in which the desired educational changes are implemented within the courses and the entire degree programme.

Overall, the paper demonstrated that through core content analysis, interviews and student surveys, a good understanding can be achieved about how to plan and implement new curriculum at the module level. Through this approach, we obtained enough information to identify existing strengths and good practices that can be built upon as well as key areas that need further improvement. In addition, the key observations and best practices can also be utilised within any engineering education context.

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Figure 1.

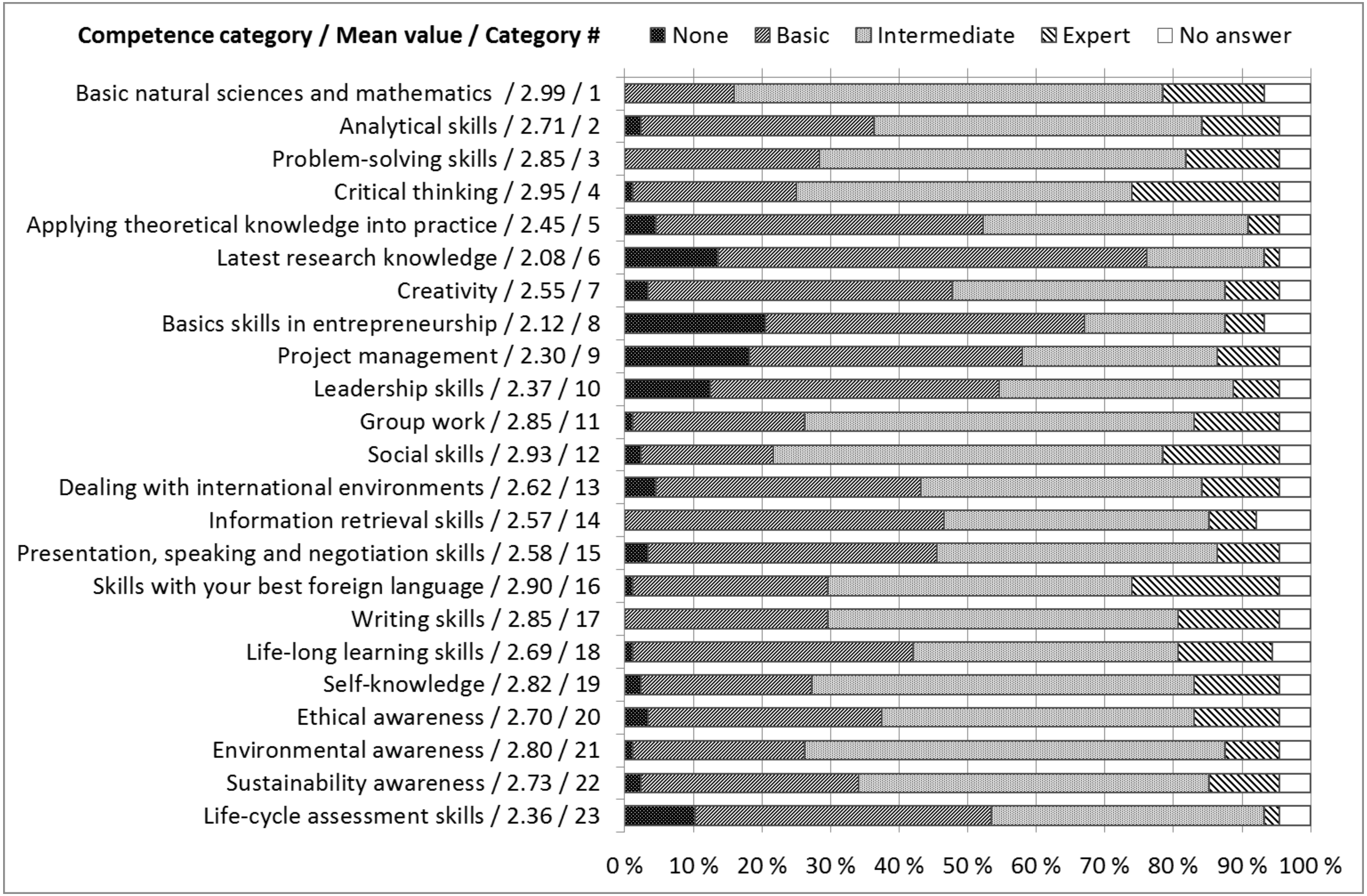
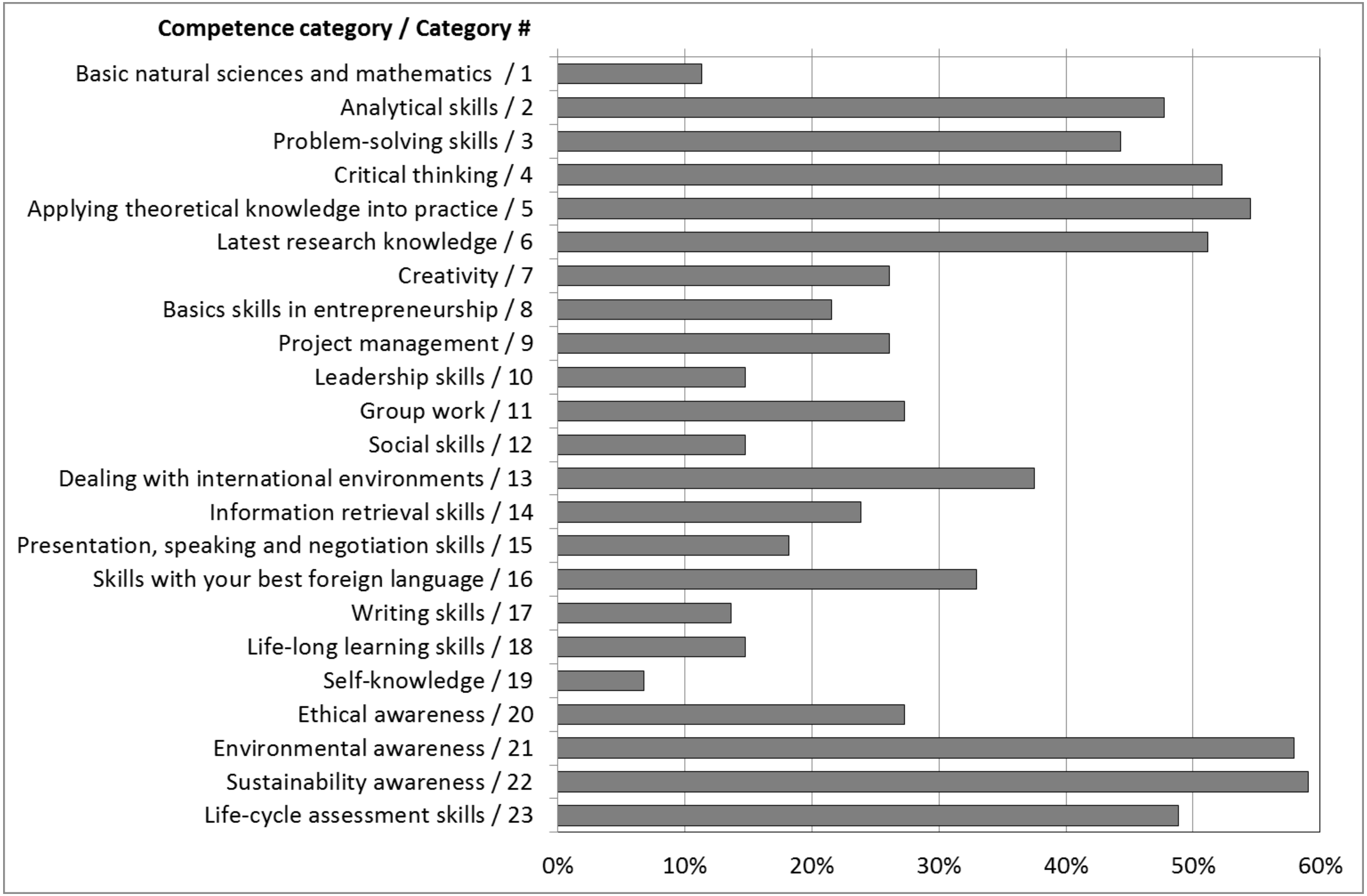
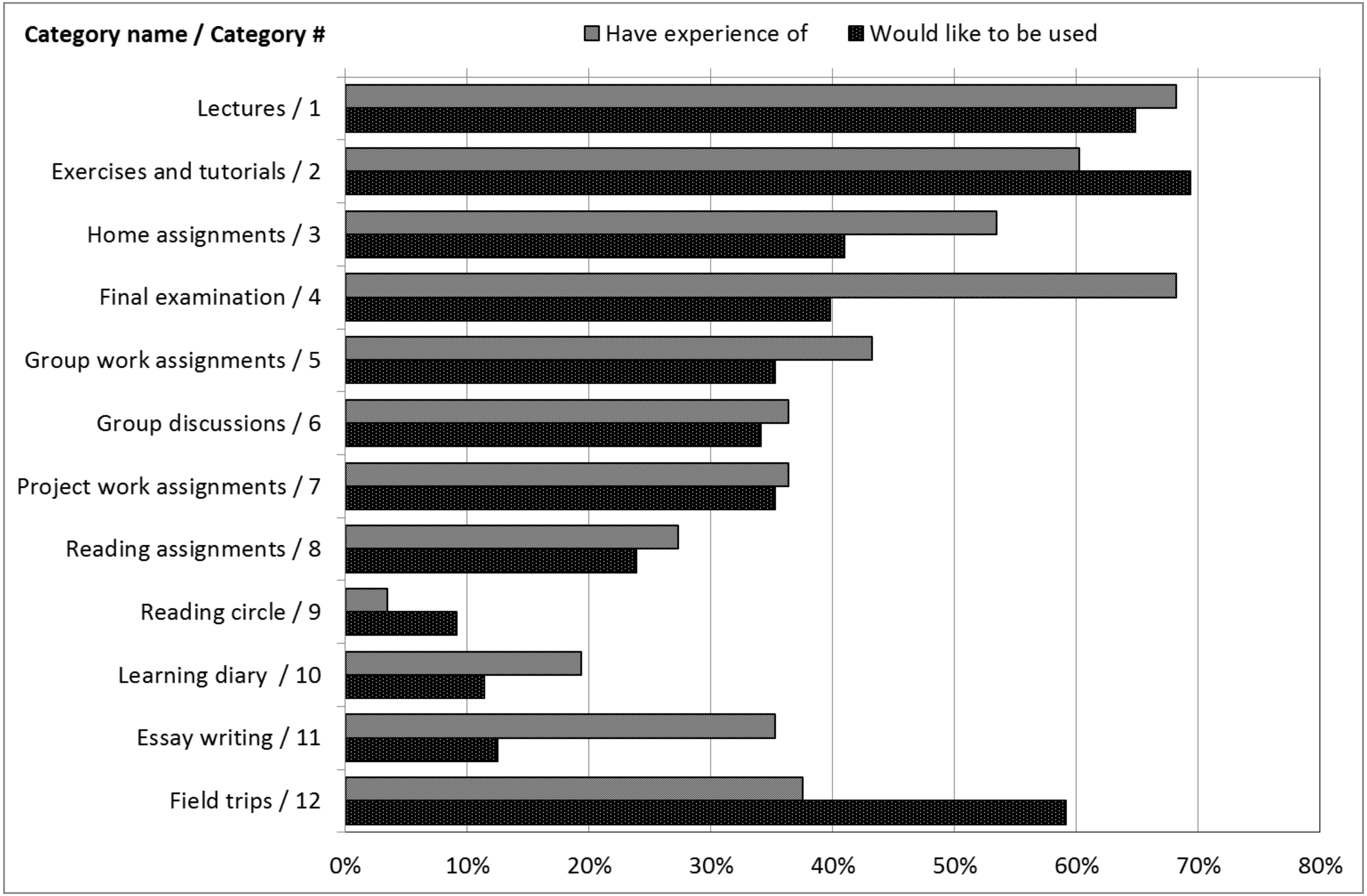

Competence category / Mean value / Category #
None
Basic
Intermediate
Expert
No answer
Basic natural sciences and mathematics / 2.99 / 1
Analytical skills / 2.71 / 2
Problem-solving skills / 2.85 / 3
Critical thinking / 2.95 / 4
Applying theoretical knowledge into practice / 2.45 / 5
Latest research knowledge / 2.08 / 6
Creativity / 2.55 / 7
Basics skills in entrepreneurship / 2.12 / 8
Project management / 2.30 / 9
Leadership skills / 2.37 / 10
Group work / 2.85 / 11
Social skills / 2.93 / 12
Dealing with international environments / 2.62 / 13
Information retrieval skills / 2.57 / 14
Presentation, speaking and negotiation skills / 2.58 / 15
Skills with your best foreign language / 2.90 / 16
Writing skills / 2.85 / 17
Life-long learning skills / 2.69 / 18
Self-knowledge / 2.82 / 19
Ethical awareness / 2.70 / 20
Environmental awareness / 2.80 / 21
Sustainability awareness / 2.73 / 22
Life-cycle assessment skills / 2.36 / 23
0 %
10 %
20 %
30 %
40 %
50 %
60 %
70 %
80 %
90 %
100 %

Figure 2.



Competence category / Category #
Basic natural sciences and mathematics / 1
Analytical skills / 2
Problem-solving skills / 3
Critical thinking / 4
Applying theoretical knowledge into practice / 5
Latest research knowledge / 6
Creativity / 7
Basics skills in entrepreneurship / 8
Project management / 9
Leadership skills / 10
Group work / 11
Social skills / 12
Dealing with international environments / 13
Information retrieval skills / 14
Presentation, speaking and negotiation skills / 15
Skills with your best foreign language / 16
Writing skills / 17
Life-long learning skills / 18
Self-knowledge / 19
Ethical awareness / 20
Environmental awareness / 21
Sustainability awareness / 22
Life-cycle assessment skills / 23
0%
10%
20%
30%
40%
50%
60%

Figure 3.



Category name / Category #
Have experience of
Would like to be used
Lectures / 1
Exercises and tutorials / 2
Home assignments / 3
Final examination / 4
Group work assignments / 5
Group discussions / 6
Project work assignments / 7
Reading assignments / 8
Reading circle / 9
Learning diary / 10
Essay writing / 11
Field trips / 12
0%
10%
20%
30%
40%
50%
60%
70%
80%

Figure 4.

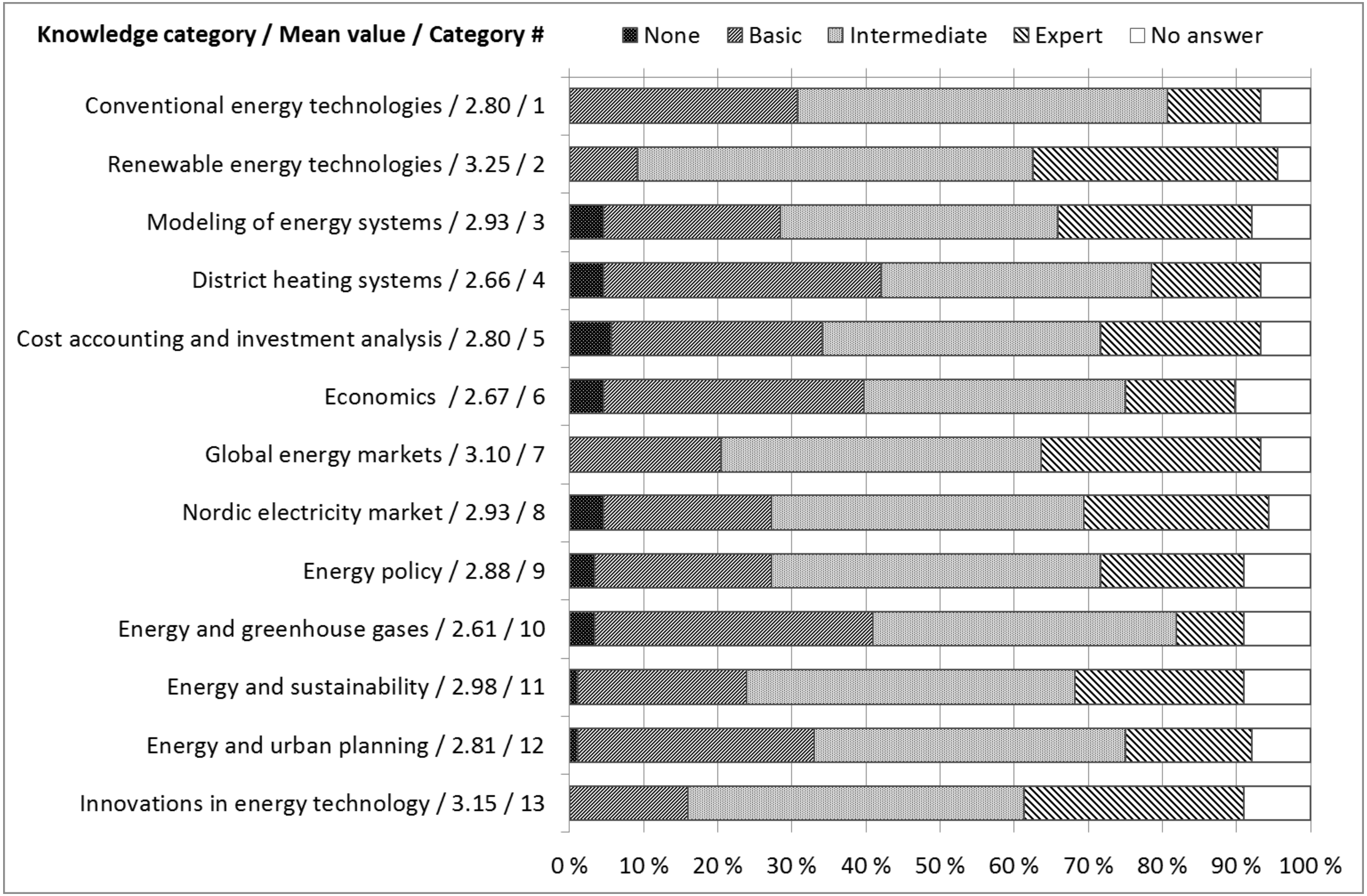

Knowledge category / Mean value / Category #
None
Basic
Intermediate
Expert
No answer
Conventional energy technologies / 2.80 / 1
Renewable energy technologies / 3.25 / 2
Modeling of energy systems / 2.93 / 3
District heating systems / 2.66 / 4
Cost accounting and investment analysis / 2.80 / 5
Economics / 2.67 / 6
Global energy markets / 3.10 / 7
Nordic electricity market / 2.93 / 8
Energy policy / 2.88 / 9
Energy and greenhouse gases / 2.61 / 10
Energy and sustainability / 2.98 / 11
Energy and urban planning / 2.81 / 12
Innovations in energy technology / 3.15 / 13
0 %
10 %
20 %
30 %
40 %
50 %
60 %
70 %
80 %
90 %
100 %

Table 1

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 Optimisation of Energy Systems	5
District Heating Engineering	5
Energy Markets	5
Energy Systems for Communities	5

Table 2

Table 2. List of working-life competencies and knowledge specific to the UESEE module used in the student questionnaire.

No	COMPETENCE	KNOWLEDGE
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 in 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	