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Article

# Building a More Sustainable Society? A Case Study on the Role of Sustainable Development in the Education and Early Career of Water and Environmental Engineers

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**Abstract:** Engineering education is critical for sustainability, given the key role that engineers have in shaping the development of our society. Yet, engineering studies have traditionally not been driven by sustainability-related knowledge and skills, but focused more on general computational skills and technical problem-solving. This has also been the case in our case study, which focuses on recent water and environmental engineering graduates in Finland. We studied the role that sustainable development has had in their education and early career through an extensive questionnaire and semi-structured interviews. The analysis was done in two ways: indirectly by comparing how well the key working life knowledge and skills recognized by the respondents correspond with sustainability-related skills, and directly by studying the graduates' views towards the sustainable development and their possibilities to advance it in their work. The results show that although sustainability was not at the core of respondents' studies, their key competencies correspond well with sustainability-related working life skills. The respondents also see that sustainable development has a central role in water and environmental engineering, although it is typically more visible at a strategic rather than a practical level. However, the results also indicate that several early-career engineers have deficient knowledge of sustainable development, and are therefore lacking the ability to fully connect the principles of sustainable development into their own expertise. Overall, the findings suggest that water and environmental engineers with their wide set of competencies have the potential to take on a larger role in building a more sustainable society. To ensure this, engineering education should emphasize the connection between the field and sustainable development and clearly link engineers' core competencies with the skills required to promote sustainability.

**Keywords:** engineering; higher education; soft skills; hard skills; knowledge; competence; sustainability; problem-solving; people skills

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## 1. Introduction

Human activities are threatening the stability of the Earth's systems [1]. Climate change, loss of biodiversity and other global problems encourage new ways of thinking and working in order to preserve life as we know it on our planet. Education at all levels should encourage people to understand the impact of their actions on future generations as well as to work towards a more sustainable world [2]. The need to incorporate sustainability and sustainable development into all fields of higher education is also widely acknowledged [3,4], calling for systemic changes in higher education [5,6].

Engineering shapes our society in a variety of ways, enabling social and economic development through technological applications and innovation. Such a role also creates a major responsibility. Many countries have their own engineering code of ethics, which sets general guidelines for the engineering profession and education, and typically also emphasize the importance of sustainability [7–9]. For example, the Finnish Association for Academic Engineers and Architects TEK notes in its Code of Honor the need to ensure a viable environment for future generations and to respect the requirements of sustainable development, while the Swedish Association of Graduate Engineers' Code emphasizes that engineers should take personal responsibility for the use of technology for the good of people, the environment and society [7] (p. 126), [8] (pp. 93–94).

While university students consider sustainability and sustainable development generally as an important and positive concept, they also seem to have incomplete knowledge of the matter [10,11]. Engineering students often connect sustainable development with environmental issues and do not link social aspects as strongly to sustainability [11–14]. As a result, university teachers have a crucial role in integrating sustainability-related knowledge and skills within courses and curricula. Such integration is not easy, however; for example, the rigidity of the existing education system and a lack of resources and new teaching methods have been recognized as barriers to incorporating sustainability in engineering education [5].

Awareness of sustainable development is not necessarily reflected in behaviour [14]. Including sustainability in higher education curricula is thus not enough; studied knowledge and skills need to be transferred to actual working life practices. Despite the increasing focus on education for sustainable development, we still have insufficient knowledge of the role of sustainable development in the working life of graduates and how graduates are able to use their sustainability-related skills in their jobs. In the engineering field, there is also a limited understanding of how well general engineering skills link to sustainability-related skills, and how they potentially connect during careers.

To enhance this understanding, this article presents the results from an explorative case study of early-career engineers in Finland. Our case study focuses on recent water and environmental engineering graduates from multidisciplinary Aalto University and its predecessor Helsinki University of Technology, and it builds on a Master's thesis partially covering the same topic [15]. We surveyed graduates' views on the most important working life knowledge and skills, and analysed these against sustainability-related skills. We also asked for graduates' perspectives on the role of sustainable development as well as their possibilities of promoting sustainability in their work. Together, this information provides a view of the role that sustainability has in the working life of early-career water and environmental engineers, and how the knowledge and skills they gained during their engineering studies promoted—or hindered—the principles of sustainable development. In this article we see sustainability as the general ability of human–nature systems to thrive and withstand change now and in the future, as well as consider sustainable development as the pathway towards that (see, e.g., [16,17]). In our survey questions we used the term sustainable development, thus focusing on the movement towards sustainability.

The article is structured in the following manner. After this introductory section, Section 2 introduces the so-called hard and soft skills related to sustainability that form the broader context of our study. After presenting the key materials and methods in Section 3, we then present the key results of our case study in Section 4 with the help of diagrams and tables. Section 5 discusses our findings from two angles, looking at the links that key working life knowledge and skills have to sustainability as well as the role that sustainability has in the water and environmental engineering field. Section 6 presents the key conclusions from the entire article.

## 2. Context: Hard and Soft Skills for Sustainability

The skills achieved during higher education and used in working life can be divided into hard and soft skills. Hard skills focus on traditional technical expertise such as computational methods and technical problem-solving, while soft skills are a combination of social and interpersonal skills,

personal qualities and career attributes [18,19]. Historically, hard skills have been the necessity for employment, particularly in the engineering field, and as a result, engineering education has focused on ensuring that students gain enough technical and computational competences. Yet the importance of soft skills in both working life and education is increasing, e.g., [20–24].

The increased importance of soft skills puts a new kind of emphasis on engineering education. Twenty-first-century engineers are considered to need diverse leadership skills, willingness for lifelong learning as well as the ability to combine technical and business knowledge [25,26]. They should also master change, be able to make decisions and take risks, and be big thinkers, team builders, good communicators, as well as ethical and courageous [25]. It is also typical that the emphasis on leadership and other soft skills increases during engineers’ careers, with hard skills more important particularly at the early stages of a career.

Global challenges and the transition towards a sustainable future call for a new set of skills as well. Several concepts describe the working life skills considered to be of special importance in the future. Table 1 lists three of these concepts [27–29]. In this article, we refer to these skills generally as sustainability-related skills. The three concepts are similar in many ways, as they all for example include skills that can be categorized into Learning & Innovation Skills as well as Life & Career Skills. However, the concepts also have differences in their specific emphasis: Future Work Skills 2020 seem to be more technologically oriented, while Sustainability Skills focus on interaction and leadership and lack direct reference to technology-related skills. In sum, these sustainability-related sets of skills can be considered as forming a hybrid between hard and soft skills, with an emphasis on soft skills.

**Table 1.** Sustainability skills [26], Future Work Skills 2020 [27] and 21st Century Skills [28] categorized in three classes.

	Learning & Innovation Skills	Information, Media & Technology Skills	Life & Career Skills
<b>21st Century Skills</b>	creativity & innovation	information, media, & ICT literacy	flexibility & adaptability
	critical thinking & problem-solving		initiative & self-direction
	communication & collaboration		social & cross-cultural skills
			productivity & accountability leadership & responsibility
<b>Future Work Skills 2020</b>	sense-making	computational thinking	social intelligence
	novel & adaptive thinking	new-media literacy	cross-cultural competency
	design mindset	virtual collaboration	transdisciplinarity
	cognitive load management		
<b>Sustainability Skills</b>	Problem-solving		leadership
			teamwork
			negotiation
			flexibility ability to maintain an exploratory attitude

This article focuses on the water and environmental engineering field, which has historically had a strong connection with the promotion of welfare, public health and sustainability. As a result, higher education in the field typically provides a combination of hard technical skills and softer skills related to broader societal development and sustainability—although with a clearly stronger emphasis on hard skills. The competence provided by such an education corresponds well with the so-called T-shaped competency profiles that aim to combine in-depth, field-specific competence (the vertical

leg of the T; in the engineering field, it is usually mainly hard skills) with broader, personal and value-related competence (the horizontal bar of the T; in the engineering field it is usually softer skills, such as management and leadership competence) [30,31]. Providing (water) engineering students with a T-shaped competency profile is seen as critical to addressing future global challenges and promoting sustainability. Yet such a task challenges engineering education to re-think its ways of learning and teaching: more weight ought to be given to flexible learning paths, group work and diverse learning environments, including experience-based learning methods such as immersive education where the learning takes place in situ in actual management contexts, and service learning, which combines learning with community service [30–33].

### 3. Materials and Methods

#### 3.1. Data Collection

The case study focuses on recent water and environmental engineering graduates from Aalto University and its predecessor, Helsinki University of Technology. Aalto University is a multidisciplinary university that was founded in 2010 by merging three universities: Helsinki University of Technology, Helsinki School of Economics, and University of Art and Design Helsinki. Aalto University is committed to shaping the future by identifying and solving societal challenges, and the university aims to integrate sustainability in all its teaching and learning [34,35]. The Master's Programme in Water and Environmental Engineering (WAT)—launched in 2016—is one of the Aalto's Master's programmes with a strong focus on sustainable development. The programme combines strong technical competence with an understanding of the wider societal context [36]. In comparison to earlier education in the field, its courses emphasize softer skills such as interaction and teamwork skills, problem-solving, and comprehensive thinking [37]. The data collected for this article also therefore serve the further development of the new WAT Master's Programme.

It is important to note, however, that the survey respondents did not include graduates from the new programme, but engineers who had graduated from Aalto University 2010–2016 or from its predecessor Helsinki University of Technology in 2007–2009. At that time water engineering and environmental engineering were taught as two separate programmes, and as a result the respondents' majors included environmental engineering, or alternatively water supply and sewerage engineering or water resources and hydraulic engineering (water engineering programme). Sustainability was not—at least explicitly—at the core of either programmes, but both focused on providing students with more traditionally hard skills such as problem-solving and computational methods. It should also be noted that a great majority of the students in environmental engineering programme already had work experience.

Two methods were used for collecting the data. A semi-quantitative questionnaire was the main method to gather information on the skills and knowledge areas that recent graduates considered to be important in their working life as well as to study the role of sustainable development in the water and environmental engineering field. In addition, a set of semi-structured interviews complemented the questionnaire survey and deepened the insights gained from the survey.

The list of graduates, their major and graduation year was received from the Dean's Unit of the Aalto School of Engineering. Contact information of the graduates was collected using LinkedIn, Google and the Fonecta directory. From the total of 191 graduates that had given their acceptance for their information to be released into alumni registry after graduation, 15 were not reached; the questionnaire was thus sent to 176 graduates. The questionnaire was sent to the respondents by e-mail in June 2017. To ensure that all recipients had sufficient time to respond, the deadline for answering was 1.5 months after the first invitation. During that time, the non-respondents received two reminders. The questionnaire included 31 questions about employment, career, skills and knowledge considered important in the field, and perceptions about the role of sustainability in the field. Examples and ideas for questions were taken from graduate surveys made by The Finnish Association

for Academic Engineers and Architects TEK [38] and the Finnish Association of Civil Engineers [39]. The questionnaire included both Likert scale questions (using scale 1–5) and open-ended questions.

Exactly half of the recipients (50%), i.e., 88 graduates, answered the questionnaire. Overall, the respondents represented the graduates well in terms of their major (chi-square test:  $\chi^2 = 0.10$ ,  $df = 3$ ,  $p = 0.80$ ) and also in terms of their gender (chi-square test:  $\chi^2 = 1.30$ ,  $df = 1$ ,  $p = 0.26$ ). Water and environmental engineers find employment in several sectors, with the private sector being the largest employment sector for them (Table 2). The second largest employer sector is water supply and sewerage/waste management companies, which are here separated into their own sector because their ownership varies. They can be private cooperatives, incorporated companies or public utilities owned by one or several municipalities, federations of municipalities, or units of municipalities. However, there are also differences in working sectors between the majors (GLM(poisson):  $\chi^2 = 37.86$ ,  $df = 18$ ,  $p = 0.004$ ). For example, according to this sample, universities are not a notable employer for environmental engineers and water supply and sewerage/waste management companies are not a notable employer for water resources and hydraulic engineers.

**Table 2.** Working sectors of the survey respondents with different majors in their studies. Water supply and sewerage/waste management companies are listed as a separate sector because they have varying ownerships, both public and private.

Sector	Water Supply & Sewerage Engineering	Water Resources & Hydraulic Engineering	Water & Environmental Engineering	Environmental Engineering	Total
Non-profit organization	0 (0%)	0 (0%)	1 (2.3%)	0 (0%)	1 (1.1%)
Central administration	2 (16.7%)	2 (10.5%)	2 (4.5%)	4 (30.8%)	10 (11.4%)
Local administration	2 (16.7%)	1 (5.3%)	2 (4.5%)	1 (7.7%)	6 (6.8%)
Research institute	0 (0%)	4 (21.1%)	3 (6.8%)	1 (7.7%)	8 (9.1%)
University	2 (16.7%)	2 (10.5%)	5 (11.4%)	0 (0%)	9 (10.2%)
Private sector	1 (25.0%)	10 (52.6%)	22 (50.0%)	5 (38.5%)	40 (45.5%)
Water supply & sewerage/Waste management company	3 (25.0%)	0 (0%)	9 (20.5%)	2 (15.4%)	14 (15.9%)

Semi-structured interviews were conducted in order to improve and deepen the picture of the skills and knowledge areas that are essential in current working life as well as the role that sustainability has in respondents' work. Four interviewees from the respondents were chosen to represent both the public and the private sectors as well as all three former majors in water and environmental engineering (Table 3).

**Table 3.** Profiles of the interviewees.

	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4
Sector	Central administration	Local administration	Research institute	Private sector
Major	Environmental engineering	Water supply & sewerage engineering	Water resources & hydraulic engineering	Water supply & sewerage engineering
Job title	Senior inspector	Planning engineer	Development engineer	Project manager
Main tasks	Inspector of Water Act	Water supply & sewerage planning	Flood risk management & watercourse regulation, development, service, research, training	Sewage surveillance & planning of treatments plants
In the field since	2003	2004	2003	2001
Engineering studies	2008–2011 (Master's studies)	2002–2007	1998–2008	2000–2007
Gender	male	female	male	female



### 3.2. Data Analysis

Basic quantitative methods and R software [40] were used to analyse the questionnaire data collected. For example, contingency tables and generalized linear models (GLM) with Gaussian or Poisson error (especially for count data) structure were used for confirming the patterns. The error structure that gave the best fit, i.e., the minimum residual deviance, was chosen for each model. The Chi-square test statistics between the original and the reduced model are reported.

To facilitate the analysis of the gathered data, both the knowledge areas and skills were grouped into categories. The knowledge areas surveyed in the questionnaire were classified into four categories: Challenges, Solutions, Practices & tools, and Other knowledge. The challenges category includes five of the nine Planetary boundaries [1,41]: climate change, cycling of phosphorus and nitrogen, eutrophication and pollution, land use change, and understanding the significance of biodiversity. The Solutions category consists of theories, and Practices & tools of more practical solutions to the problems. The Other knowledge category includes knowledge of fields other than water and environmental engineering. Similarly, working life skills surveyed were categorized into six groups using the modified classification of [42]: Practical skills, Communication & group work skills, Social skills, Sustainable development skills, Leadership skills, and Scientific methods. It is important to note that these categories were not visible to the respondents and were used only during the analysis phase.

Conventional content analysis was used for qualitative data analysis (open-ended questions and theme interviews) [43]. In this study, the importance of working life skills is evaluated using the soft/hard skills concept and the Sustainability Skills [27], Future Work Skills 2020 [28] and 21st-Century Skills [29] concepts. The reliability of the classification regarding the opinions on the sustainable development theme in the Master's programme was ensured with a two-step approach. The classification was data-based, according to the opinions, and afterwards it was checked that all the opinions fit the assigned categories.

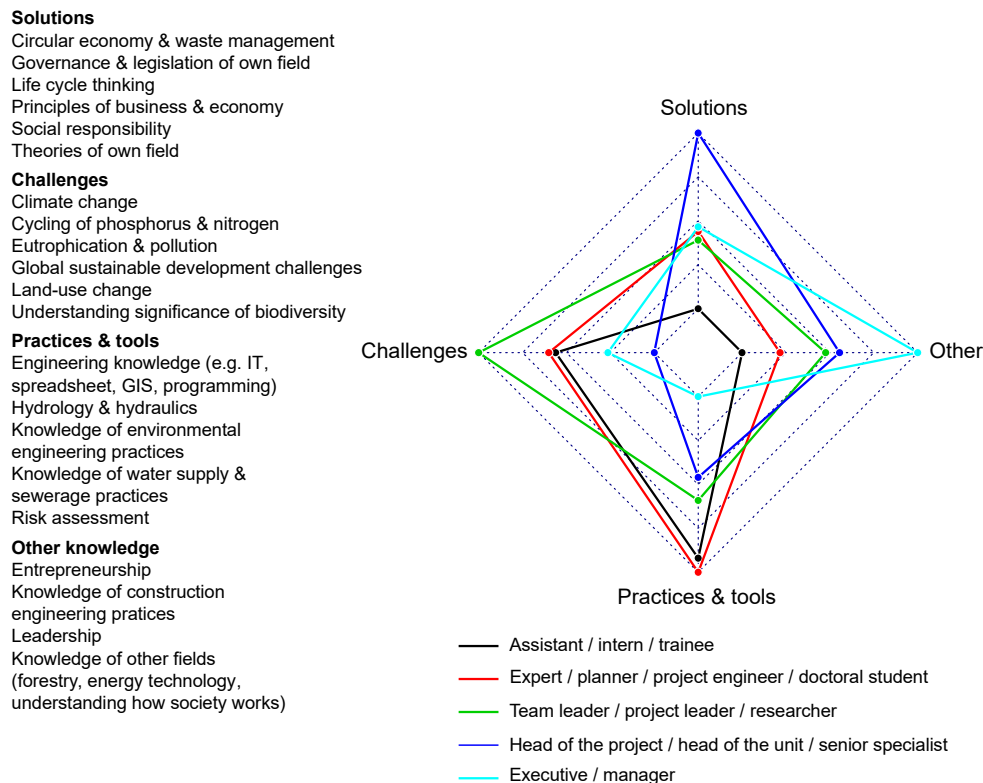
## 4. Results

### 4.1. Important Knowledge Areas

To understand the key knowledge areas for recent water and environmental engineering graduates, the survey respondents were first asked to choose five knowledge areas that they consider the most important for the different hierarchical levels at which they have worked. The knowledge areas were classified into four categories during the analysis: Challenges, Solutions, Practices and tools, and Other knowledge. Practices and tools was the most important knowledge category on the assistant and the expert levels, whereas Solutions was the most important knowledge category for leader, head and manager level engineers (Figure 1). Those two knowledge categories were the two most important for engineers on every hierarchical level—only managers and also head-level engineers, somewhat, were expected to master other fields (Figure 1). Category Challenges was more important on the team leader level than on any other hierarchical level. On the two highest hierarchical levels, Challenges was the least important knowledge category.

According to the respondents, there were four knowledge areas that stand out from the rest. The most important knowledge area for water and environmental engineers was Governance and legislation in one's own field. It was considered to be one of the most important knowledge areas on every job level except executives and managers. Knowledge of governance and legislation of one's own field was especially important for engineers working as officials in a central or local administration and for those whose major was environmental engineering. The second most important area of knowledge, Hydrology and hydraulics, was also important on all levels, except for executives and managers. It was considered important especially by those working in central administration and by those who studied water resources and hydraulic engineering as their major. Theories of own field and Knowledge of water supply and sewerage practices were important especially on the assistant and expert level jobs, and they were needed especially by respondents working in universities and

local administration, respectively. Leadership was considered to be the most important knowledge for executives and managers. Knowledge areas categorized as Challenges were not considered to be of top priority for water and environmental engineers. Land use change and Climate change were the most essential knowledge from the category. Climate change knowledge was important for engineers working in universities. When asked about important knowledge areas, one of the four interviewees mentioned climate change and sustainable development. The research institute representative considered knowledge of climate change as one of the core knowledge areas in his job. Furthermore, understanding of the sustainable development concept was essential for him as it is important to mention sustainability in funding applications.

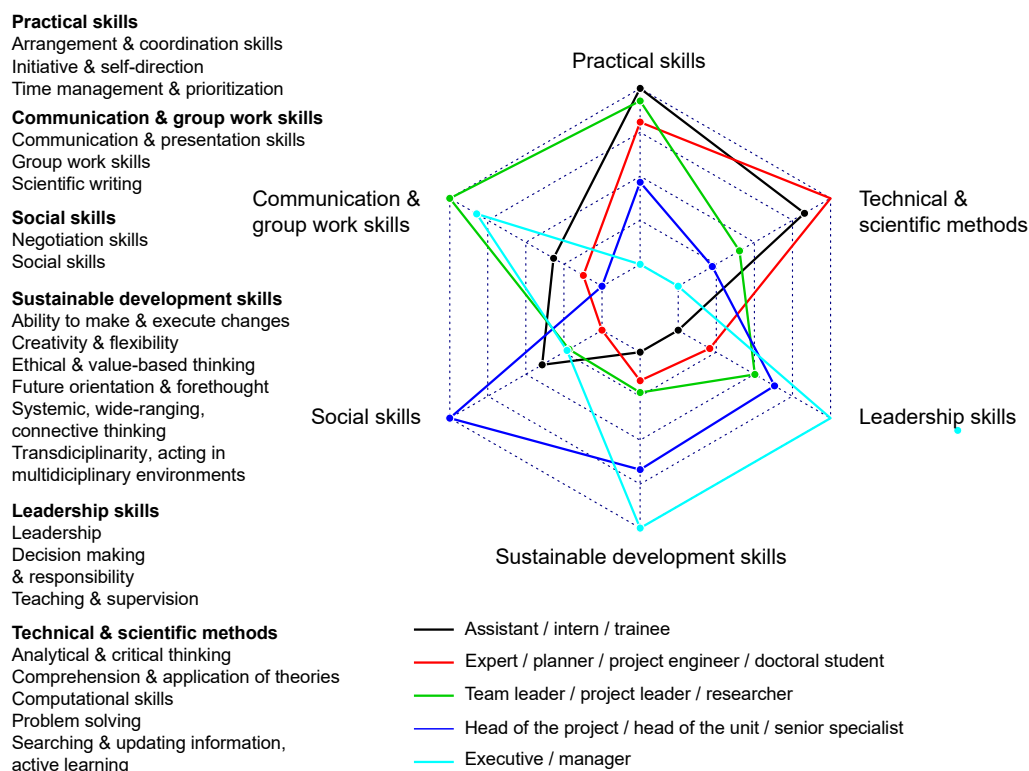


**Figure 1.** The most important knowledge for different work levels: Comparison between work levels. Assistant level  $n = 24$ , expert level  $n = 80$ , team leader level  $n = 21$ , head of the project level  $n = 9$ , executive level  $n = 3$ .

#### 4.2. Important Working Life Skills

The respondents were also asked to choose five skills that they consider the most important for the work levels at which they have worked. The skills were divided into six categories during the analysis: Practical skills, Communication and group work skills, Social skills, Sustainable development skills, Leadership skills, and Technical and scientific methods. Technical and scientific methods were considered important on the assistant and expert levels—more important for them than for any other work level (Figure 2). Practical skills were the most important skills category for team leaders, but in comparison to other work levels, Communication and group work skills were more important for team leaders than for anybody else (Figure 2). The category of Sustainable development skills was the most important for heads of projects and managerial-level engineers (Figure 2). When compared to other levels, Social skills were more important for the head of project level, and leadership skills for manager level than for any other work levels (Figure 2).





**Figure 2.** The most important skills for different work levels: Comparison between work levels. Assistant level  $n = 33$ , expert level  $n = 82$ , team leader level  $n = 28$ , head of the project level  $n = 15$ , executive level  $n = 10$ .

The single most important working life skill was Time management and prioritization, which was considered to be one of the most important skills of all, except for executives and managers. The next important skills were Initiative and self-direction and Searching and updating information, active learning, which were especially important for assistants and experts. Problem-solving skill was important for expert-level engineers, and Future orientation and forethought as well as Decision-making and responsibility were essential skills for heads of projects and managerial-level engineers. In addition, Communication and presentation skills and Leadership were also considered important for executives and managers.

All of the four interviewees listed both soft and hard skills when they were asked about the most essential skills in their current jobs; however, none of them mentioned the skills classified as Sustainable development skills. People skills, especially fluent and clear writing skills, were mentioned by all. The officials from local and central administration emphasized the importance of comprehensible text that is understandable for a wide audience, from policy-makers, consultants and other officials to private citizens. They both also made a strong argument for grammatically correct text. In addition, other people skills as well as presentation, meeting and social skills were important for all interviewees. The questionnaire respondents evaluated problem-solving as one of the most important skills for expert-level engineers; however, the private sector representative was the only interviewee who mentioned problem-solving as one of the most essential skills in her everyday toolbox. Almost all the interviewees were doing at least some modelling; thus, modelling skills and the use of modelling software were essential in their current jobs.

### 4.3. Role of Sustainable Development in the Field

The survey respondents were also asked directly about the role that sustainable development plays in their field. A clear majority of the respondents in water and environmental engineering (64%) said that their current or former job is connected to sustainable development. Engineers who have studied water resources and hydraulic engineering as their major most often had a job that is connected to sustainable development; for other majors the connection was present in approximately half of the cases. Thus, sustainable development connection of jobs was not dependent on the major (GLM(poisson):  $\chi^2 = 2.86$ ,  $df = 3$ ,  $p = 0.41$ ). The ones who were working in the private sector or in universities more often had jobs that were connected to sustainable development, whereas in water supply and sewerage/waste management companies the connection was missing in most of the cases. The differences in sustainable development connections of jobs between the sectors was not statistically significant (GLM(poisson):  $\chi^2 = 5.65$ ,  $df = 6$ ,  $p = 0.46$ ). Furthermore, sustainable connection of jobs was not dependent on gender (GLM(poisson):  $\chi^2 = 0.002$ ,  $df = 1$ ,  $p = 0.96$ ) or work level (GLM(poisson):  $\chi^2 = 2.26$ ,  $df = 3$ ,  $p = 0.52$ ).

When the interviewees were asked to define sustainable development, they were all focusing on ecological development; however, research institute and private sector representatives also mentioned the social and economic aspects of sustainable development. The two interviewees whose majors had been water supply and sewerage engineering (who were both women) emphasized future generations in their definition.

*Well, it means that we act so that the future generations can also enjoy some of the same things, or that we do not destroy the environment, nor . . . I do not know the definition by heart, but it includes also social effects and the economic effects are there too, right?*

*Maybe I would mostly connect it with it that we have the carbon-neutral city and all, so that at least we do not leave a worse legacy than what we have now. On the contrary, that we would leave a better situation for the future generations. That we would try both in everyday life and in planning work to make such decisions that naturally decrease emissions and restrain climate change. And leave behind at least as good and preferably a better environment.*

The definition of the research institute representative was a bit more pessimistic. He said that as we follow the terms of economic growth, we have to act so that we do not destroy nature more, and even try to restore it. While mentioning culture and social aspects, he used words like respectfully and sustainably. The sustainable development definition of the central administration official was the most mechanical of the four. He saw sustainable development to be human activity that does not cause consumption of natural resources or pollution. Development of technology will assist with sustainable development.

Differences between the public and private sectors became more obvious when the interviewees were asked about the role of sustainable development in their jobs. All three public sector representatives saw it being built into the job. Sustainable development is an everyday matter; work aims at reaching ecological sustainability and strives to act according to its principles. In the private sector, on the other hand, the focus is on serving customers, and if the customer does not specifically ask to take sustainability issues into account, they will not necessarily be acknowledged. The private sector representative mentioned that, just recently, sustainable development has become a matter that is discussed in larger contexts; however, the ways to implement its principles in every task have not been scrutinized.

While the central administration official supposed that sustainable development was not considered in everyday work because of its built-in nature, sustainable development had a central role in the operations of the local administration and research institute. The municipality in question took part in many sustainability projects, for example to cut down on greenhouse gas emissions. It was also taken into account in the office culture. The research institute in question took part in several international sustainable development-related teams. The 17 United Nation's Sustainable

Development Goals [44] were visible in different contexts, and because the research institute was a large organization, practical know-how for all of them could be found in house.

#### 4.4. Sustainable Development Content of Studies

The respondents were also asked how satisfied they were with sustainable development-related contents in their studies. Interestingly, the responses indicated some differences between the majors, with environmental engineering majors being the most satisfied and water supply and sewerage engineering majors the least satisfied; the differences were, however, statistically non-significant (GLM(poisson):  $\chi^2 = 0.50$ ,  $df = 3$ ,  $p = 0.92$ ). The level of the current job did not influence satisfaction over the sustainable development content of the studies either. The ones who were heads of projects, heads of units or senior researchers were the least satisfied, but they were not many (GLM(poisson):  $\chi^2 = 1.34$ ,  $df = 3$ ,  $p = 0.72$ ).

In their written answers, four respondents said that their studies did not offer information about how to act according to sustainable development principles in their jobs or offered information very poorly. One of them justified the answer by saying that she does not know the principles of sustainable development. Of the 14 respondents who thought that the studies offered poor information about sustainable development, a few said that it is difficult to find any other contact between the field and sustainable development than developmental projects, or that sustainable development was introduced as a separate concept without any connection to practice. Two respondents replied that they were extremely happy with sustainable development content in their studies.

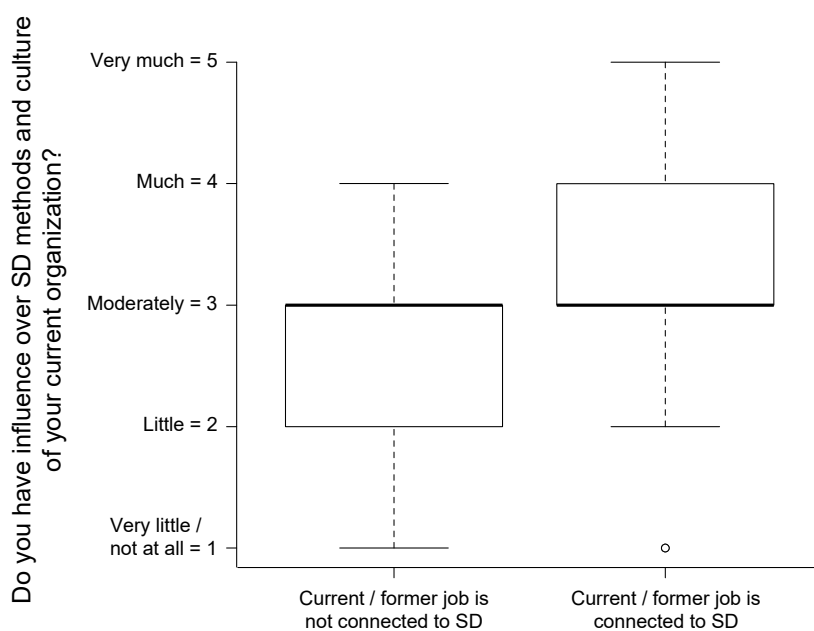
The four interviewees were also asked if their attitudes and thoughts about sustainable development had changed since their studies. Only the interviewee working in central administration said that his attitudes had stayed the same, and that he saw sustainable development being mostly linked with recycling and materials efficiency. The interviewee from the local administration similarly connected sustainable development with recycling in her studies. According to her, sustainable development and its principles were not present in water supply and sewerage engineering studies. However, work has increased her knowledge about sustainable development, with climate change as a big driver for its current visibility. The attitudes and thoughts of interviewees from research institute and the private sector towards sustainable development had changed since their studies. While the interviewee from the research institute thought that he might have missed the topic totally in the studies because of lack of interest, nowadays he completely accepts the importance of the concept. The interviewee working in the private sector was an environmentally conscious young adult, and chose her field of study for that reason. She also said that sustainable development issues were covered in the studies. Interestingly, she studied the same major and partly during the same time as the interviewee from local administration; however, their recollections of the study contents differ strongly in terms of sustainable development. The results indicate that the differing values and interests of students may influence what they pay attention to in their studies.

#### 4.5. Power over Sustainable Development Methods and Culture

Given the close connection between the water and environmental engineering field and sustainability, it is also interesting to see how early-career engineers are able to promote sustainable development in their work. Overall, the respondents felt that they had moderate power to influence sustainable development methods and culture in their current organizations. Water supply and sewerage engineering majors had a slightly higher perception of their influence over sustainable development methods and culture than graduates with other majors, but the difference was not statistically significant (GLM(poisson):  $\chi^2 = 0.88$ ,  $df = 3$ ,  $p = 0.83$ ). Also, the hierarchical level of the job seemed to be disconnected from the power over sustainability decisions; only the ones on the executive manager level could clearly influence the sustainable development methods and culture of their current organizations (GLM(poisson):  $\chi^2 = 1.65$ ,  $df = 3$ ,  $p = 0.65$ ). Low influence was explained by low position in the hierarchy or the fact that price affects decision-making more than anything

else. However, open answers reflected even more positive influencing possibilities. Respondents had the only knowledge of sustainable development matters in the organization; they were part of the team developing the sustainable development culture and methods, or they could take into account sustainable development principles in planning processes.

Like with the satisfaction over the sustainable development content of the studies, the respondents whose former or current job was connected to sustainable development also perceived their influence over sustainable development methods and culture in their organization to be greater than those whose former job was not, in their opinion, connected to sustainable development (Figure 3). However, the difference in power perceptions between the two groups was not statistically significant (GLM(poisson):  $\chi^2 = 2.46$ ,  $df = 1$ ,  $p = 0.12$ ).



**Figure 3.** Influence over sustainable development methods and culture in current job organization of those who see that their current or former job is or is not connected to sustainable development. The boxes show the range of the upper and lower quartiles; bold horizontal bars indicate the median; whiskers show the smallest and largest values (1.5 times the interquartile range); and the values outside this range are depicted by open circles.

#### 4.6. Perceptions of the Suitability of the Sustainable Development Theme for the Master's Programme

Sustainability is a key cross-cutting theme for the new Master's programme in Water and Environmental Engineering at Aalto University: such an emphasis marks a clear change to the previous programmes the survey respondents had studied in. The questionnaire respondents were therefore asked for their perceptions on including sustainable development with such a strong focus in the field's higher education. The responses varied from extremely positive to extremely negative, and we therefore classified them into four categories between those extremes (Table 4). Three inconsistent replies were not included in any of the categories. Over half of the 60 replies to this question were positive, indicating that having sustainability as a key theme in the new Master's programme is a good thing. The second largest group were those who are positive but with some preconditions, connected, e.g., with ensuring that the studies still have a strong connection to practice. Only 10 percent (i.e., six respondents) had a negative perception of having sustainable development as the central (or cross-cutting or key) theme in the Master's programme.

**Table 4.** Classified perceptions with justifications of sustainable development being one of the central and crosscutting themes of the new Master's programme in Water and Environmental Engineering.

1 Negative Opinion <i>n</i> = 6	2 Hesitant <i>n</i> = 7	3 Positive with Preconditions <i>n</i> = 11	4 Positive Opinion <i>n</i> = 33
Programme should concentrate on basic technical science	Not essential for the field, decisions based on money	Must become concrete in studies/connection with practice ensured	Relates to everything/should be considered in all actions
Engineers should be able to calculate & solve problems	Definition vague	Definition vague	All-embracing
Interdisciplinary, takes focus from engineering towards humanities	Old-fashioned	Quite theoretical	Timely, forward-looking
Does not help with job search		Worn-out phrase	Essential, important
Jargon, no connection to concrete matters			

Interestingly, the respondents' majors and work sectors seemed to partly explain their views on sustainability and its inclusion in the field's education. Water supply and sewerage engineering majors had the most negative perceptions about the sustainable development theme. Water resources and hydraulic engineering majors, water and environmental engineering and environmental engineering majors had very similar opinions about the theme. The same trend was seen when looking at the working sectors; the ones working in water supply and sewerage/waste management companies were the most critical. Doctoral students working in universities were the most homogeneous group. They all had positive attitudes towards the sustainable development theme; however, most of them had preconditions. Whether or not the current or former job was connected to sustainable development did not affect the perception about sustainable development being one of the central themes for the Master's programme. Furthermore, satisfaction over the sustainable development content of the studies and gender did not explain the perceptions (GLM(poisson): sector  $\chi^2 = 2.28$ ,  $df = 6$ ,  $p = 0.89$ ; SD connection of job  $\chi^2 = 0.023$ ,  $df = 1$ ,  $p = 0.87$ ; SD content of studies  $\chi^2 = 0.25$ ,  $df = 1$ ,  $p = 0.62$ ; gender  $\chi^2 = 0.11$ ,  $df = 1$ ,  $p = 0.74$ ; major  $\chi^2 = 2.18$ ,  $df = 3$ ,  $p = 0.54$ ).

## 5. Discussion

### 5.1. Key Working Life Knowledge and Skills and Their Link to Sustainability

The results indicate that most of the skills that are considered essential in water and environmental engineers' early career are generic skills that could be prioritized in basically any field. It is notable, however, that a majority of the key skills are soft skills, including skills in categories such as Communication and group work skills, Social skills and Leadership skills (Figure 2). In terms of key knowledge areas, the responses differ between the hierarchical work levels (Figure 1), with field-specific engineering knowledge (Practices and tools) being particularly important for lower work level engineers and broader knowledge related to Solutions and Other knowledge on higher work levels. Interestingly, the Challenges category (which includes sustainability, climate change and other global key drivers and challenges) emerged as particularly important at the middle work level (team leaders/project leaders/researchers), with both lower and, particularly, higher work level engineers considering it less important.

According to our survey results, the single most important working life skill for early-career water and environmental engineers is time management and prioritization, which was categorized into Practical skills. This probably reflects the present hectic work culture more than anything else. Also, three of the four interviewees said that their timetables had intensified during their career. However, none of the interviewees explicitly mentioned time-management skills as an important skill

in their work; this is most likely because it is such an obvious skill that it does not come to mind in open discussions but is chosen if alternatives are given (as in our survey). This was also observed by Passow and Passow [45] in their recent systematic review analysing the relative importance of generic engineering competencies. Time management and prioritization has also been considered a key working life skill in surveys of engineering graduates in Finland [38,46].

The importance of key soft skills, namely Communication and group work skills, Social skills and Leadership skills, is clearly visible in the survey responses as well. Their importance also tends to increase along the respondents' careers, with Communication and group work skills as well as Leadership skills being particularly important among executives and managers, and Social skills among the heads of projects/units. The four interviewees all mentioned people skills, social skills, and especially fluent writing skills as core skills in their jobs. This is in line with the results from a recent survey of water and environmental engineering graduates in Finland: the survey found that an overwhelming majority of the respondents found social skills (100%), team working skills (95%), communications skills (94%) and leadership skills (74%) to be an important part of their working life [45]. Similar findings were noted by Takala [47], whose interviews with eight water supply and sanitation experts in Finland emphasized holistic understanding of the water sector, common sense and the ability to communicate with a variety of stakeholders as the most important competencies. As noted by Passow & Passow [45], engineers might spend more than half of their workday communicating, and effective communication through listening, oral, written and graphic means is a core competence for a present-day engineer.

When thinking of the traditional view on key skills needed in engineering, it is intriguing to note that generic engineering skills (i.e., hard skills), such as computational skills, were not among the skills most selected by the respondents of our survey. On the other hand, another traditional engineering skill, problem-solving (which can here be considered a hybrid skill between hard and soft skills), was considered to be among the most important skills at the expert level that was also the most common level of the respondents. The limited emphasis on the importance of hard skills is likely to highlight the diversity of tasks among the respondents as well as the fact that the respondents were allowed to select only five skills per level from a given set of skills, although the respondents were also given the opportunity to add their own skills. Such a conclusion was supported by the interviews. When asked about the core skills needed in their jobs, the interviewees also typically mentioned specific engineering skills such as the ability to use a certain software and modelling skills, as well as Geographic Information Systems (GIS) and Information and Communication Technology (ICT) skills.

As working life skills and knowledge areas were separated in the survey, the more specific competencies are mostly listed as knowledge areas. The most important knowledge areas also reflect the major and working sector more than the key working life skills. For example, governance and legislation in one's own field is especially important for engineers working in the public sector, and hydrology and hydraulics for those who studied water resources and hydraulic engineering as their major. The more generic knowledge category, Challenges, is not considered to be among the top priorities. The results indicate that the respondents seem to be focusing on solving problems, but possibly predominantly with pre-determined solutions and without thinking too much about the origins of those problems. Interestingly, the respondents working in universities prioritize climate change knowledge more than engineers employed in other sectors, which reflects its role in research. This finding is supported by the interview with the research institute representative, who named climate change as one of the core knowledge areas in his work.

In sum, the results from the survey and interviews indicate that early-career water and environmental engineers consider their working life to require a broad set of knowledge and skills, with an emphasis on soft skills that stress communication, leadership and social skills. The more traditional engineering (hard) skills such as computational skills and problem-solving carry less weight, although their importance is more notable at lower hierarchical levels. Such a combination of soft and



hard skills is similar to the sustainability-related set of skills listed in Table 1, indicating that the current requirements of the (water and environmental) engineering field may already at present correspond relatively well with future-orientated sustainability-related skills.

### 5.2. *The Role of Sustainability in the Water and Environmental Engineering Field*

The respondents were also asked about their views on sustainable development in their field. Although sustainability was not at the core of respondent's own studies, a clear majority saw their work being connected with sustainable development. Exactly half of the questionnaire respondents had a positive or somewhat positive opinion about sustainable development being one of the core themes in the new Master's programme in Water and Environmental Engineering. The justifications for the respondents' views (Table 4) can be seen to reflect their expectations and concerns, also related to sustainable development more generally. The most positive opinions highlight the all-embracing nature of the concept and point out that sustainable development principles should be taken into account in all actions. The positive justifications also emphasize the importance of sustainable development at this very moment, seeing it as a particularly timely concept. Interestingly, the negative views partially employ the same arguments, but these respondents see that the all-embracing, interdisciplinary nature of sustainability may shift the focus too far from traditional engineering, and it should therefore be excluded from engineering education. It thus seems that respondents' views towards sustainability—positive or negative—are not so much related to their understanding of the concept per se, but more to their values, beliefs and personality. Such a finding is supported by Brown et al. [48], who identified three persona types among engineering educators regarding their beliefs and the practice of integrating sustainability into their teaching. One of the persona types expresses a high level of dogmatism, which is reflected in a relatively closed belief system that actively prevents the person from accepting new ideas [48]. Similar perceptions were expressed by some of the Finnish engineering teachers in a study by Takala and Korhonen-Yrjänheikki [49]. The teachers had concerns that incorporating sustainable development into engineering education also demands broader, systemic thinking that could endanger specialization, as less time would be available for teaching technical knowledge and skills. Most of the interviewed teachers thought that it is possible—and essential—to cover both wider contexts and specific technical competencies [49].

Because of its ambiguous and process-type nature as well as the preference for inter- and transdisciplinarity, sustainable development can be seen to challenge engineers and engineering education, which is typically accustomed to dealing with and focusing on facts and technical problem-solving (see [49] and the references therein). This was also evident in our study. Some respondents saw the vagueness of sustainable development as a major challenge. For example, one of the interviewees felt that the vagueness hampers a person's ability to describe the role that sustainability has at the organization level. On the other hand, all the interviewees emphasized the in-built nature of sustainability, and could pinpoint existing strengths as well as potential for improvement in terms of the sustainability in their work. With this, the interviewees showed an understanding of the concept, being able to discuss its role at different levels. One of the interviewees and also some questionnaire respondents expressed quite mechanistic views of sustainability, suggesting that purely technological advancements could be the solution to sustainability challenges. Such mechanistic and rationalistic approaches might miss out on the dynamic and multifaceted nature of sustainable development, neglecting the root causes of sustainability challenges [50,51].

Our results indicate that a notable proportion of the water and environmental engineers have deficient capacity and/or willingness to connect their work with sustainable development. One-third of the questionnaire respondents, including people working, for example, on waste management, climate change adaptation and environmental management, indicated that their former or current job is not connected to sustainable development. Part of the reason may be the respondents' narrow view on sustainability, with a majority of interviewees, for example, connecting the sustainability-related content of their studies with environmental engineering and recycling. On the other hand, a majority

of the respondents were moderately satisfied with the sustainable development content of their studies, with the ones whose current or former job has a connection to sustainability being slightly more satisfied. As also noted by Starcic et al. [14], our results suggest that sustainable development themes should be contextualized and applied in practice in order to improve learning outcomes.

One important finding from our study is the limited ability that early-career water and environmental engineers have to influence sustainability methods and culture in their organizations. Some of the reasons for this are likely to include the respondents' low rank and narrow responsibilities within the hierarchy. At the same time, however, many respondents as well as interviewees expressed both the will and the know-how to do more in relation to sustainable development, supporting the findings of other studies [49]. This mismatch between willingness and actual capacity to promote sustainability in their work may link to the broader role that engineers are expected to have in society. Finnish engineers, for example, have been described as invisible because of the passive role that they have adopted in society, with a focus on solving problems (defined largely by others) [49,52]. Given the key role that engineers have in society, the future focus should shift from finding single solutions to defining and understanding complex inter- and transdisciplinary problems in collaboration with other disciplines [49,51].

## 6. Conclusions

This article looked at early-career water and environmental engineers in Finland, focusing on their key knowledge and skills as well as the role that sustainability has in their education and work. Our case study shows that Finnish water and environmental engineers have various important roles, and their expertise is required in several sectors of society. Sustainable development has a central role in the field of water and environmental engineering, with the majority of the respondents seeing their work as related with sustainability.

Traditional (hard) engineering skills, such as computational methods and technical problem-solving are still needed and valued at work, and they also form the core of engineering education. Yet, an emphasis in working life is increasingly on softer skills: social skills as well as communication and leadership. This mix of knowledge and skills corresponds well with the so-called sustainable development skills, or future working life skills. As a result, the core competencies provided by existing engineering education can—at least in Finland—also be seen to contribute to the promotion of sustainable development. They also correspond with the idea of T-shaped expert competence, with more traditional engineering competences forming the foundation and broader, and softer skills forming links to adjacent disciplines and sectors as well as to society at large.

Yet, several early-career water and environmental engineers seem to have a limited understanding of sustainability, being incapable of fully connecting the principles of sustainable development to their own expertise and everyday work. Interestingly, the wide-ranging and vague nature of sustainability as a concept is seen as both an asset and a hindrance in promoting sustainability in the water and environmental engineering field. Those with the biggest concerns about the applicability of sustainable development in their field see it only as a nice theory with little practical relevance, while others see sustainability as an inherent part of their field.

The results also indicate that while sustainable development is strongly present at the meta-level, i.e., in the visions and values of respondents' organizations, it is not as clearly visible in the everyday tasks of water and environmental engineers. In addition, while the majority of recent water and environmental engineering graduates have both the skills and the willingness to promote sustainability, they do not (yet) have the proper possibilities to capitalize on this fully in their work, nor the power to push sustainability in their organizations. This suggests that incorporating sustainable development into water and environmental engineering requires clarifying its role in the field and an increased emphasis on collaboration with other fields in defining and solving sustainability-related challenges. This presents a challenge for engineering education, which should simultaneously provide students with a broad understanding of society and its sustainability challenges as well as field-specific technical

competencies. Aalto University's new Master's programme in Water and Environmental Engineering aims to do exactly this, and a follow-up study is therefore needed in the future to compare the competences and views of those graduates to the respondents of this study.

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