

Sustainability Competence in Computer Science Education

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ABSTRACT: Digitalisation creates opportunities and challenges, both socially and environmentally. Are computer science students interested in addressing these opportunities and challenges and is their education providing them the desired competencies? Theoretically, the paper focuses on the concept of competency and presents the eight sustainability competencies formulated in UNESCO's Education for the Sustainable Development Goals. Two sets of data are analysed to address the research questions: data from a questionnaire focusing on their aspirations for future work and data from a deductive content analysis of the learning outcomes of six bachelor programmes in informatics. Sustainability-related factors scored important/very important in the aspirations for future work. The analysis of the learning outcomes indicates a very weak connection between learning goals and sustainability competencies. An integrative approach is proposed, which may contribute to the development of sustainability competencies that enable the students to take up normative and critical positions in digitalisation and sustainability discourses.

1. INTRODUCTION

In 1990, Kristen Nygaard received the Norbert Wiener Award for Social and Professional Responsibility. Nygaard was at that time professor at the Department of Informatics (IFI) at the University of Oslo and received the award for "his pioneering work in Norway to develop 'participatory design', which seeks the direct involvement of workers in the development of the computer-based tools they use" (CPSR, 2008; Hegna, 2020).

Thirty years later, Nygaard's pioneering work is still relevant. Digitalisation, such as AI and robotics, is changing how we work and where we work and the scale on which digitalisation takes place is creating new challenges. New information technologies and digitalisation processes can strengthen the social sustainability of our societies, but at the same time they contribute to undermining central earth-system processes (Cologna et al., 2020; Rockström et al., 2009; Steffen et al., 2015). For example, the increasing production, storage, use, and discard of data and digital devices contributes to increasing CO₂ levels and decreasing biodiversity.

This brief background inspired two research questions: 1) Do students at IFI want to engage with social, ethical, and environmental challenges in their future work life, and 2) Does computer science education at IFI offers them the competencies to address these challenges in their future work life? This paper provides some preliminary answers. In the next section we describe briefly our research approach, centred around sustainability competencies. Section 3 presents the data followed by the discussion in Section 4, which focuses on linking the results of the analysis of the two datasets.

2. RESEARCH APPROACH

2.1. Competency

The central focus in this study is on competencies for sustainability. Competency refers to the effective application of knowledge and skills for problem solving in a particular context (Adam, 2006; Westera, 2001). Wiek et al. (2016) define competency as "a functionally linked complex of knowledge, skills, and attitudes that enable successful task performance and problem solving" (p. 242). In a university education setting, competencies should not be described too general or too specific (Mulder et al., 2009).

In terms of the competence that enables students to “engage with social, ethical, and environmental challenges in their future work life”, a range of competencies are needed. We understand these as sustainability competencies, the integration of knowledge, skills, and attitudes that enable successful task performance and problem solving for social and environmental sustainability. In this study we use the Sustainable Development Goals (SDGs) (United Nations, 2015) as a proxy for our understanding of sustainability. In the context of education for the SDGs, the United Nations Educational, Scientific, and Cultural Organisation (UNESCO) identifies eight key competencies for sustainability (Rieckmann et al., 2017) (see Fig. 1), which we used as analytical lens to discuss our results:

Systems thinking competency: the abilities to recognize and understand relationships; to analyse complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty.

Anticipatory competency: the abilities to understand and evaluate multiple futures – possible, probable and desirable; to create one’s own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes.

Normative competency: the abilities to understand and reflect on the norms and values that underlie one’s actions; and to negotiate sustainability values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions.

Strategic competency: the abilities to collectively develop and implement innovative actions that further sustainability at the local level and further afield.

Collaboration competency: the abilities to learn from others; to understand and respect the needs, perspectives and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem solving.

Critical thinking competency: the ability to question norms, practices and opinions; to reflect on own one’s values, perceptions and actions; and to take a position in the sustainability discourse.

Self-awareness competency: the ability to reflect on one’s own role in the local community and (global) society; to continually evaluate and further motivate one’s actions; and to deal with one’s feelings and desires.

Integrated problem-solving competency: the overarching ability to apply different problem-solving frame-

Fig. 1. Key sustainability competences (Rieckmann et al, 2017, p. 10)

2.2. Methods

For the past ten years, new bachelor students at IFI answered a questionnaire at their first day of study. It aims to identify the importance of various factors related to the motivation and expectations of new students – with regard to their studies, but also future job opportunities. We used the questions from the Lily project (Norwegian: Vilje-con-valg), which also included questions on study background, study plans, gender, and the importance of various recruitment activities and information channels that informed their choice (Naturfagsenteret, 2010). The Lily project aims “to develop new knowledge and theoretical perspectives, and to stimulate informed discussion, of how to recruit and retain more young people in science, technology, engineering, and mathematics (STEM) careers” and was initiated by the Norwegian Centre for Science Education and the Department of Physics, University of Oslo, in 2008 (Naturfagsenteret, 2020).

We used datasets from 2011-2013, 2015, and 2017-2020, focusing on one question: “How important are the following factors for you regarding your future work?”. The students could indicate the importance of a factor on a Likert scale from 1-4, with 1=not important and 4=very important. There were 36 factors (Naturfagsenteret, 2010), but our focus here is on seven factors that had a reference to sustainability: (a) Help other people; (b) Sustainable development, justice, and protection of the environment; (c) Working with something that is important for society; (d) Working with something that is compatible with my values and attitudes; (e) Working on something that I find meaningful; (q) Design something that means something to other people; and (u) Development of renewable energy technology.

In order to answer our second research question, we implemented a deductive content analysis (Krippendorff, 2018), on the text of the learning goals of the six bachelor programmes at IFI. These learning goals give a general overview of what the students can expect to learn in the programme; they are

divided in knowledge, skills, and general competence goals. We coded the texts of the learning goals based on the eight competences for sustainability (Rieckmann et al., 2017).

3. RESULTS

3.1. Aspirations for my future career

Fig. 2 presents the ranking of the seven factors as well as the average of all 36 factors.

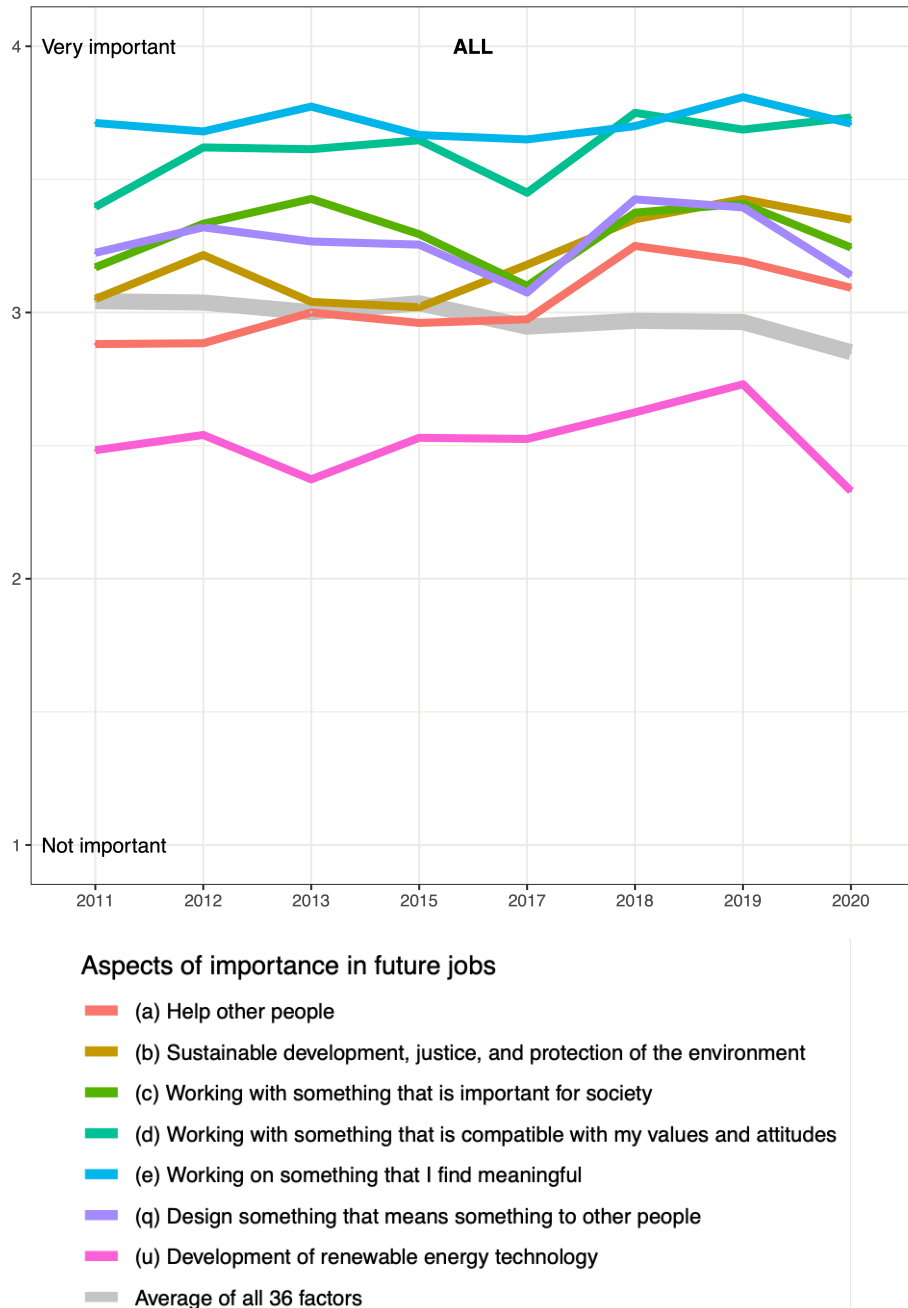


Fig. 2. All respondents

3.2. Bachelor programmes at IFI

The sample consisted of texts presenting the learning outcomes of the six bachelor programmes at IFI.¹ We coded the texts manually, using a simple codebook based on the eight competences for sustainability (Rieckmann et al., 2017):

- Systems thinking competency – **codes**: System; Relationships; Complexity; Uncertainty
- Anticipatory competency – **codes**: Future(s); Precautionary principle; Consequences; Risks
- Normative competency – **codes**: Values, Trade-offs; Sustainability
- Strategic competency – **codes**: Strategic; Local; Global
- Collaboration competency – **codes**: Collaboration; Participatory
- Critical thinking competency – **codes**: Norms; Values; Reflexivity
- Self-awareness competency – **code**: Self-reflection
- Integrated problem-solving competency – **code**: Integrative

The results are presented in Fig 3.

Competencies	Electronics, Informatics, Technology	Design, Use, Interaction	Digital Economy	Programming, Systems Architecture	Robotics, Intelligent Systems	Language
Systems thinking	✓					
Anticipatory					✓	✓
Normative						
Strategic						
Collaboration		✓				✓
Critical thinking	✓	✓	✓	✓		✓
Self-awareness		✓	✓	✓		✓
Integrated problem-solving						

Legend

- Electronics, Informatics, Technology
- Design, Use, Interaction
- Digital Economy
- Programming, Systems Architecture
- Robotics, Intelligent Systems
- Language

Fig 3. Sustainability competencies in bachelor programmes at IFI

4. DISCUSSION AND CONCLUDING REMARKS

This study presents a first brief evaluation of how computer science education matches the job aspirations of bachelor students at IFI. The two personal factors (d) Working with something that is compatible with my values and attitudes, and (e) Working on something I find meaningful, rank consistently between 3.5 and 4. The main sustainability factor (b) Sustainable development, justice, and protection of the environment has ranked consistently between 3 and 3.5. The others are also above average, with exception of (a) Help other people, in the first two years, and (u), which consistently scores low. The latter should not come to a surprise, as the formulation is very specific.

In sum, the answer on RQ 1 is confirmative: students at IFI want to engage with social, ethical, and environmental challenges in their future work life. In terms of RQ 2, the situation is different. Bachelor programmes at IFI present learning goals as a list of knowledge, skills, and general competences. Knowledge and skills are not integrated into higher-level competencies. The language of the programmes' learning outcomes is very specific when it comes to a description of the subject knowledge and skills the student will gain through the programme and very general when it comes to sustainability competences. Several of the programmes use similar phrases to refer to the general competence students will achieve through the programme, e.g., "You can reflect over the central ethical, societal, and professional challenges in relation to one's own and other's work"², without going into detail what these might be. The findings represented in Figure 3 give a very general indication of the availability

¹ IFI bachelor programmes: <https://www.mn.uio.no/ifi/studier/programmer/#bachelor>

² For example: <https://www.uio.no/studier/program/informatikk-programmering/hva-lerer-du/>

terms and sentences that can be understood as contributing to sustainability competency, however, none of the learning outcomes texts use terms such as values, justice, sustainability, uncertainty, and future(s).

4.1. An integrative approach

Dhouhá et al. (2019) argue that sustainability competences inevitably include personal dimensions, such as values, emotions, and motivation. New bachelor students at IFI rank future work that is value-based, meaningful, and compatible with their attitudes consistently as important/very important. Integrating these personal dimensions with programme-specific competences, knowledge and skills may result in the development of important normative competences, both as part of general sustainability competency as well as the critical thinking competency needed to explore the norms and practices in computer science and to take a position in current and future digitalisation and sustainability discourses (Dlouhá et al., 2019).

4.2. Future research

The programme competences and learning goals evaluated in this study provide only superficial insight in what students actually learn. It might be relevant to take a closer look at the actual course curricula and possibly interview lecturers and/or students about their views.

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