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Development of Sustainability Competencies in a Higher Education Semester Program on Smart Sustainable Cities

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Abstract

Cities face enormous challenges regarding their sustainable development. Facing these challenges requires a range of competencies that enable professionals to in-depth analyse problems, envisage multiple futures, reflect on norms and on their own actions and beliefs and develop innovative solutions in a multidisciplinary approach. For students in Higher Education to develop these competencies, an elective semester program was designed and implemented, the learning effect of which was determined through self-assessment by the participating students. Results show that students report strong or slight improvement on most of the six key sustainability competencies, most significantly on self-awareness, strategic and normative competencies. In addition, students learn from the application of design skills in the program. This paper demonstrates a relation between the program components and self-reported growth in sustainability competencies. Further research is deemed necessary to explain exactly how competency development is fostered by the didactical approach and content of the program.

Keywords: *Sustainability competencies, design skills, interdisciplinary cooperation, smart sustainable cities.*

1. Introduction

Cities face enormous challenges on the road to a sustainable future, such as inclusion, climate adaptation, mobility, circular use of materials, a healthy environment for all and sustainable business propositions (Vandecasteele *et al.*, 2019), while information and communication technology, offering a wealth of data, is increasingly being used to monitor developments and contribute to solutions (Haarstad, 2017). This 'Smart Sustainable City' paradigm requires an interdisciplinary or transdisciplinary approach to study and solve problems (Bibri, 2018).

Students in higher education must learn how to deal with these challenges. Therefore, we designed and piloted, together with our European partner universities, a one semester study program (Eweg & Rietbergen, 2019; HU, 2017). This minor program on Smart Sustainable Cities (SSC) is an elective course of 30 European credits (EC) that students can take next to their major study program. From 2018 on, it was offered to Dutch students as well as students from universities that comply with the requirements for student exchange with our own.

The minor SSC was designed with the following principles, requirements and ambitions in mind: it should be a multidisciplinary program, combining various disciplines from social science, engineering and economics in about equal amounts. It takes an applied research approach, aimed at problem solving and solution design. After taking the course, students will:

- demonstrate knowledge and insight from various disciplines in challenges for SSC;
- understand and discuss practical situations in the context of SSC with a client;
- put into practice a number of methods and techniques for analysing SSC challenges;
- research and design creative sustainable solutions for SSC;
- communicate these solutions effectively, both orally and in writing;
- reflect on their results as a team and their own professional contribution to it.

The program has now been offered successfully to four consecutive groups of students. Among the latest group, of September 2021, we aimed to establish whether students taking the course have indeed developed the competencies that we intended during its design. Our research question was: 'to what extent do students feel they have developed key sustainability competencies and, in particular, multidisciplinary work, analytical and design skills?'

2. Key Sustainability Competencies

Several sets of competencies, associated with sustainable development, have been proposed. In this research, the five competencies were used that were proposed by Wiek *et al*. (2011): systems-thinking, anticipatory, normative, strategic, and interpersonal competencies. A sixth competency, self-awareness, was added, i.e. the competency to reflect on one's own actions, results and feelings (UNESCO, 2017). These competencies are detailed in Table 1.

Table 1. Key Sustainability Competencies (based on Wieck et al., 2011 and UNESCO, 2017).

Competency	Description
Systems thinking competency	The 'ability to recognize and understand relationships, to analyse complex systems, to perceive the ways in which systems are embedded within different domains and different scales, and to deal with uncertainty'. It requires knowledge about (the complexity of) system theories, skills such as interdisciplinary thinking and seeing interconnections, and the attitude of curiosity and perseverance.
Anticipatory competency	The 'ability to understand and evaluate multiple futures – possible, probable and desirable – and 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'. It requires knowledge about the past, trends and novelties to build future scenario's, skills such as critical and creative thinking, and attitudes like flexibility and curiosity.
Normative competency	The 'ability 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'. It requires knowledge about different norms and values about sustainability depending on the perspective, skills like critical thinking, and attitudes like being receptive for other views.
Strategic competency	The 'ability to jointly develop and implement innovative actions that promote sustainability at the local level and beyond'. It requires knowledge about applicable strategies, skills like action planning, problem-solving and attitudes like positivity.
Self-awareness competency	The 'ability to reflect on one's own role in the local community and (global) society, continually evaluate and further motivate one's actions, and deal with one's feelings and desires'. It requires self-knowledge, skills such as being resilient, developing an own world view, engaging to a sustainable society; and attitudes such a being open to self-reflection.
Interpersonal competence	The 'ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving' It requires knowledge about e.g. other cultures, collaboration skills, diversity skills, and an open attitude towards other people's culture, beliefs etc.

3. The Minor SSC Program

The minor consists of a ten week course and a multidisciplinary 'Sustainability Challenge' project. The course offers students a variety of topics, indicated in Table 2. Each weekly topic is taught through lectures and assignments. Design thinking skills (Karhu and Rietbergen,

2020) are included to make students understand real human needs, identify opportunities and conceive, prototype and test creative solutions for smart sustainable city challenges. In week 5, students participate in a challenge: mixed student teams design solutions to make the busy Utrecht Science Park a liveable, green and sustainable place for all who use it. The last two weeks of the course, the students apply most of what they have learned to a small project for a real life client, e.g. a municipality; in 2021, this was about town expansion in a highway zone. Across the first six weeks, they develop a research plan for this project.

During the second period of ten weeks, the Sustainability Challenge, students explore the assignment given by a real client, and design smart, creative and innovative solutions, often in the form of a viable commercial proposition. All assignments include project management and communication with the client and are multidisciplinary in character, so that all students can contribute to the solution from their own discipline. There is an opportunity to carry out projects abroad. Examples of past projects are: advise about a substantial reduction in CO_2 emissions from traffic in the city of Alcoy (Spain) or design an effective marketing campaign to promote cycling in the Greater Manchester region (UK).

In parallel to the course, students are given assignments that help them develop into a reflective professional. Based on several personality and group work tests, they write a personal development plan and discuss it with their peers. They receive feedback and monitor their development during the course and the project. They practice and apply multiple methods to reflect on significant situations and record their progress in an e-portfolio.

Table 2. Minor SSC Course Content.

Week	Topic	Contents
1	Introduction	Students get to know their group, activate prior knowledge, have an introductory class on SSC and do their first assignments
2	Design	A4DT design thinking method, analysis with empathy, work with persona's, phases in the double diamond, future probing, value sensitive design
3	People	Quality of life, human needs, behaviour and behaviour change, urban psychology, excursion, World climate game
4	Planet	Energy, carbon footprint, life cycle analysis, circular economy, sustainable mobility
5	Intermission	Students engage in a sustainable campus challenge, organised separately by the Utrecht Challenge Alliance
6	Health	The positive health concept, urban health scan method
7	Profit	Business Model Canvas, including several assignments to elaborate it
8	Smart	Big data analysis, CRISP-DM, GIS analysis
9 / 10	Project	Design innovative, smart and sustainable solutions for an urban sustainability challenge of an external client

4. Method

Students were asked to complete a survey in which they were asked to mention one or two topics from the course that they were most familiar with from their own discipline. Students could also indicate one or two subjects that they found most interesting, that they learned the most about and that they applied most during their work on the highway zone project.

Next, the survey presented the six sustainability competencies, using the descriptions shown in Table 1, and students were asked to assess the extent to which, during the course, they had developed each competency on a four point scale, from 'strongly improved' to 'my level at the beginning of the minor was already beyond the level expected'. With each competency, students could elaborate on their score on the four point scale. In addition, students were asked to also assess their development with respect to multidisciplinary cooperation, analytical skills and design skills. The same scale was used, including space for comments. The survey was held at the end of the last class of the course. Independently, we analysed students' reflections on the program, recorded in their e-portfolios.

5. Results

In the September 2021 course, twenty students had enrolled from six different countries (Finland, Germany, Hungary, the Netherlands, Turkey and the UK) and fourteen different study backgrounds. All students (100%) completed the survey.

Table 3 lists the topics that students found most akin to their own major field of study, that they found most interesting, about which they learned the most, and that they applied most in the project. Topics found to be most akin to the major fields of study were 'planet', 'smart' and social topics. The challenge week was found most interesting, followed by 'people' and 'smart' aspects of SSC. Clearly, design skills were applied most in the highway zone project.

Figure 1 shows students' self-assessment of their competency development. Depending on the competency, 65 to 80 % of students find that they have slightly or strongly improved with respect to the key sustainability competencies. Strong improvement is most often scored for self-awareness (40%), followed by strategic and normative competency (both 25%). With respect to skills, students clearly indicate strong improvement on design and multidisciplinary cooperation skills (45% and 30%, respectively).

When examining the overall reflections in students' e-portfolios, we found that they mostly made comments on generic skills, which is unsurprising, since in the e-portfolio assignments they choose three generic skills from a list to develop and monitor their progress. One student commented: "*I am more creative and innovative than I thought. I gained more organizing skills and found out that I already have some analytic skills that I maybe took for granted*". Another: "*The programme is primarily designed for independent learning, and I think*

Table 3. Minor SSC Course Content.

Topic	Most Akin	Most Interesting	Most Learned	Most Applied
Design	3		5	8
People	6	9	5	2
Planet	9	3	3	5
Challenge	1	11	5	2
Health			3	5
Profit	3	1	2	3
Smart	9	5	2	
Project	3	1	4	
Other				1[a]

a = Sustainable energy

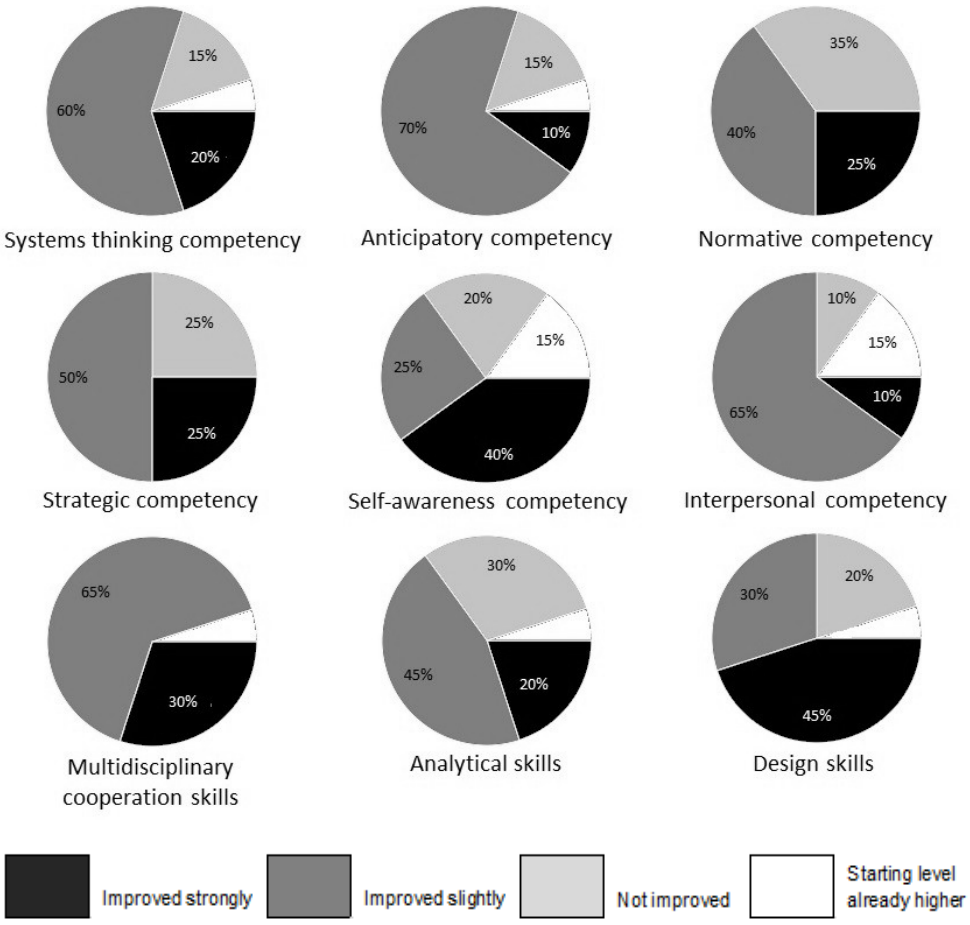

Figure 1. Competency development (students' self-assessment).

that this has helped me personally to develop further. I learned a lot about design processes and scientific methods for finding solutions in the field of sustainability. I especially liked the practical relevance and the fact that new topics were discussed every week, so a broad spectrum of knowledge was conveyed. Through that I gained a lot of new knowledge".

6. Discussion and conclusion

Amidst of the competencies, self-awareness stands out; it is most likely promoted by the reflection assignments students did almost every week. One student commented that they had "*never been so reflective in my entire life*". However, students' comments and e-portfolio reflections indicate that most did not particularly like these assignments and preferred lectures on subjects related to urban sustainability. The strategic competency is also developed by many students. This competency entails action planning and joint problem solving (cf. Table 1). As many students indicated they learned most from either the sustainable campus challenge or the project, it seems quite probable that a challenge- or project-based didactical approach is suited for developing this competency. However, students indicate that they struggle with the seemingly chaotic structure of the minor and the many assignments they have to do in parallel. The relatively high score (25% strongly improved) for the normative competency cannot be readily explained from the elaborations given. It might be caused by the many enthusiastic and pleasant discussions among the students during classes. Further research is needed to find out how our didactical approach stimulated development of this competency. Systems thinking and anticipatory competencies also proved to be developed; the scores for 'improved strongly' and 'improved slightly' add up to 80% for both. As the program does not focus explicitly on complex systems, nor on visions of a sustainable future, but rather on problem analysis and design of solutions, this is not really surprising.

The interpersonal competency was only slightly improved according to most (60%) students, whereas 10% indicated strong improvement. However, 80% of students indicate that they have strongly (30%) or slightly (65%) improved on multidisciplinary cooperation skills, that entail similar capacities. The difference might be explained by the fact that this competency was formulated in more abstract terms (Table 1) than students' own ideas about interdisciplinary cooperation. In comments, students often mention that they have learned to work with fellow students from different nationalities, cultures and major study backgrounds.

With respect to skills, 45% of our respondents indicate strong development. Two students elaborated that they had never done anything similar and, therefore, made a huge leap in their development of this skill. One respondent added that the design classes were applied almost every week of the course. On the other hand, five out of 20 students think they already possessed this skill. This applies to two students from industrial engineering and one from

landscape planning and design, studies that focus strongly on design skills. Both other low scores are a bit puzzling. The high improvement on interdisciplinary cooperation skills is unsurprising in view of the diverse major study backgrounds of the participants of the minor.

We conclude that a minor program in which a diversity of students, with respect to both their major field of study and their nationality / cultural background, are enrolled and are offered tools for analysis and design of innovative solutions, contributes to the development of key sustainability competencies. The focus on design thinking enables many students, especially those that had no prior experience in design, to strongly improve their design skills. A continuous program of reflective assignments, along classes about the 'people', 'planet', 'profit' and 'smart' themes, helps students to develop their self-awareness competencies.

We aim to research students' competency development in more detail by assessing performance on indicators for each competency – rather than by self-assessment. In addition, we aim to clarify the actual mechanisms through which the program's learning activities contribute to competency development, in order to improve the learning effect of the program and increase our shared knowledge about sustainable development education. Also, further analysis of the achieved sustainable development competencies is required by detailing the knowledge, skills and attitudes that are entailed in the six key sustainability competencies.

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