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On A Computer Science Master Program For Sustainable Development

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ABSTRACT

Sustainable development and the UN's Sustainable Development Goals have been pointed out as crucial for our common future, addressing several aspects of a world to be considered as sustainable. From a university perspective it is certainly interesting, and important, to see how research and education contribute to that context, which may be seen from both disciplinary, and multi-disciplinary perspectives.

A one-year Master Program in Computer Science for Sustainable Development, at Kristianstad University (HKR), Sweden, has a background in the UN's Agenda 2030, and in statements, claiming that 'at the edge'-techniques, from areas such as Artificial Intelligence, and Datamining are crucial to approach each and one of Agenda 2030's 17 Sustainable Development Goals. With this background, that Master program, was initiated to provide, for students at a master level, challenging disciplinary subjects, as well as an interesting and valuable context to contribute to, with their technical skills. To furthermore approach the students' maturity in the field, the program is supported by courses regarding, on one hand (1), Sustainable Development, and how Computer Science generally may contribute, and on the other hand (2), advanced projects where concepts and techniques shall be practiced within research contexts. It shall also be mentioned that the program is open for students internationally, thus bringing further interesting values through the mutual sharing of experiences from international perspectives. This contribution intends to provide an overview of the program, as well as a more in-depth presentation of the two above-mentioned courses.

1 INTRODUCTION

The United Nation's Agenda 2030 was adopted in September 2015, and explicitly pointed out 17 Sustainable Development Goals (the SDGs) to be achieved in 2030. While those goals ([1]) address several critical areas, such as, *No Poverty*, *Zero Hunger*, and Good Health and Well-Being (SDGs 1, 2, and 3), one goal especially

addresses cooperation to accelerate the achievement of the SDGs, that is, goal 17, *Partnerships for the Goals*. Today, there exists a number of national as well as regional Sustainable Development Solutions Networks (SDSN) ([2]), and where especially SDSN NE (NE stands for Northern Europe), organizes the northern nations of Europe, including Denmark, Finland, Norway, and Sweden, for cooperative actions in the context of Agenda 2030.

The launch of SDSN NE took place in Gothenburg, Sweden, in February 2016. HKR (the home university of the author) was represented by the author of this paper (amongst others). At that launch, Swedish business and political leaders were invited to participate, along with engaged academics and representatives of several organizations, such as the UN and the Swedish International Development Cooperation Agency ([3]), showing the high ambitions for the SDSN NE, as well as for the Agenda 2030 at large. At that meeting, furthermore, IT was singled out several times as essential to achieving each of the 17 SDGs. Not only was IT mentioned in general, but cross-cutting techniques such as Big Data, AI, and the Internet of Things (IoT) in particular ([3]). It can be mentioned, IT or Computer Science, does not explicitly correspond to any of the SDGs but is nevertheless considered to be crucial for the fulfilment of each of them ([4]).

Meanwhile, at that point in time, the Dept. of Computer Science at HKR (CS@HKR) was struggling with its previous master program in computer science. That program should have a focus on Embedded Systems but was rather diffuse in nature and difficult to get a comprehensive understanding of. It was therefore perceived as a need to revise the master's program in order to have a clearer and more well-motivated structure. The launch of the SDSN NE could in this context be seen as a source of inspiration to revise that master program in a direction towards how Computer Science (and IT generally) may contribute to Sustainable Development (SD). In such as program, concepts of SD would in that case be emphasized, and interesting and valuable techniques addressed.

1.1 Meeting Legal Demands on Sustainability in Education

Regarding this contribution from another perspective, the Swedish Higher Education Act ([5]) clearly states that SD should be considered at the Swedish universities, and that concepts of SD should be included in the universities' various courses. In 2017, to follow up how well the Swedish universities lived up to those directives, a survey was organized by the Swedish Higher Education Authority ([6]). The result showed a rather depressing result ([7]), only about 25% lived up to the directives, and then about 75% (including HKR) needed to do more or less exhaustive work on course design, as well as on administrative routines to improve their approaches towards SD.

Requirements for sustainable development in the computer science programs were generally difficult to relate to. But with inspiration from the launch of the SDSN NE, it was possible to see that there was in fact a lot that could be approached. Moreover, from the perspective of several technologies, approaching the SDGs could furthermore be seen of interest to students as well as to researchers and teachers.

In the light of the above, in September 2017 it was decided that a revised master's program in computer science should have an overarching focus on SD,

encompassing interesting techniques to meet SD, and clearly be related to surrounding societal interests. Like the previous master's program, the revised program should be open internationally, with potentials to contribute to additional values regarding SD. The program is a one-year master's program and was provided for the first time in autumn 2018.

1.2 On Prerequisites for Teaching and Learning on SD

According to [8], Higher Education has a critical role in advancing the agenda of SD, and where educating for SD can be considered a natural way to ensure SD. Already since the Stockholm conference in 1972, the significance of sustainability ([9]), in Higher Education has been recognized for its important role in fostering society towards SD. Still, as pointed out by [3], barriers emerges when higher education institutions do not establish incentive systems that promote changes at the individual level. Lack of time, and administrative support, thus, make it difficult to integrate SD in higher education institutions ([3]). The re-designing of curricula is a relatively easy part, but efforts that imply organizational members to hold shared assumptions about SD and take the lead in society demand something else ([8]).

The demands for improvements on SD at HKR, were primarily approached through an investigation into the circumstances of HKR, and suggestions on how to improve ([8]). In a report resulting from that investigation, a pedagogical course for HKR's educators was proposed ([10]), among other things. That course was launched at 2018, piloted with educators from CS@HKR in 2018. It has then been open for all educators at HKR ([11]), thus contributing to inter-disciplinarity, or cross-faculty approaches towards SD ([12]). The course emphasizes SD generally, experience sharing amongst colleagues, and tasks regarding curricula and course development towards SD, all in all to support the educators with capacities for SD teaching and learning at their respective study programs and courses.

2 METHODOLOGY

The one-year Master Programme *Applied Computer Science for Sustainable Development*[1] has as an overall goal that '*the student, after graduation, should be able to work with and lead the development of complex computer-assisted systems with an independent, critical and interdisciplinary overall view, in order to meet the multidisciplinary needs, found in different contexts related to sustainable development*'. To support for this, a structure of the study program must concern aspects on SD, as well as skills in advanced techniques of computer science. Furthermore, to be able to act effectively in contexts of multi-disciplinary challenges, project courses should bind together technical skills and apply those in contexts outside computer science, and with contributions to SD. Furthermore, demands are especially put on master programmes in being research oriented. That is, technique-oriented courses as well as SD-concept-oriented and project-oriented courses must reflect on research themes. An overall structure of the program is illustrated by Fig. 1, and where the timeline of the program follows the numberings of the blocks, and where 'CS methods 4 SD' runs over the whole first autumn semester.

[1] Applied Computer Science for Sustainable Development: One-Year Master Programme - 60 credits, https://www.hkr.se/en/program/computerscience-master

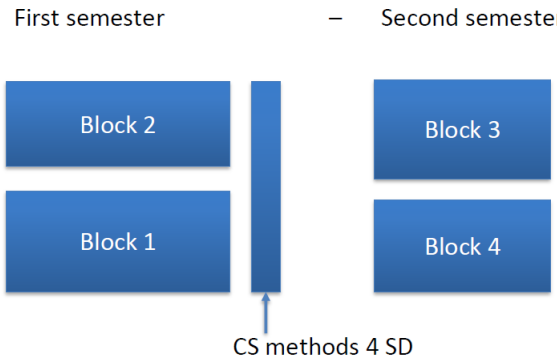

Fig. 1. Outline of a one-year program

Moreover, students should be able to meet challenges where sensor-data in Internet of Things-based systems may reveal, for instance, air quality, or states in agriculture. Data should be collected and withdrawn through methods of datamining and interpreted through AI or Machine Learning. Furthermore, results should be monitored, preferably at handheld devices independent on underlying technology. Also, the communicating data and results should be made secure. Thus, the blocks are furthermore outlined as follows:

- **Block 1**
  - Mobile platform development
  - Wireless communication and security
- **Block 2**
  - Internet of Things
  - Machine Learning
- **Block 3**
  - Project, multi-disciplinary
  - Data Mining
- **Block 4**
  - Thesis Project
- **and also, CS Methods for SD**
  - Generic skills, Science and methodology
  - Self-reflection and self-awareness
  - The context of the Agenda 2030, and Computer Science for SD

This contribution will especially focus on two of the courses that have been given by the author of this paper, that is, *Computer Science Methods and Sustainable Development*, and *Project in Multidisciplinary Contexts*. The structures and main contents are outlined in the sequel.

2.1 Computer Science Methods and Sustainable Development

First, the syllabus of the course[2] clearly addresses the context of SD to the course, and furthermore points out ethical aspects as significant. Second, the course aims to

[2] Computer Science Methods and Sustainable Development - 6 credits, https://www.hkr.se/en/course/DT580C/course-syllabus

practice generic skills, such as searching and reading scientific material, and make oral and written presentations. The main components of the course are *Lectures*, *Exercises,* and a *Design Project*.

The lectures are supported by literature with focus on general perspectives on SD[3], Computational Sustainability[4], Research Methodology[5], and several scientific articles, and internet-based material. Assignments of the exercises follow the lectures and shall provide a basis for further understanding. Moreover, the exercises contain elements of self-reflective training, with the intent to support for approaching mature views on SD, and especially on IT for SD. All is presented in the class and discussed amongst the students and the teacher, which should bring even further values to the matters discussed.

Themes of assignments include:

- Design a digital user interface that should be used to inform the common public about SD.
- Study one of the ICT contributions to the 17 SDGs, from *'Fast-forward_progress_report_414709 FINAL.pdf'*, present it to the co-students, and initiate discussions.
- Study articles on ethical aspects, for instance, with respect to the AI revolution coming fast. Present and discuss in class.

Self-reflective training was conducted iteratively during the exercises and were structured around a quite large number of statements, that the students should reflect on individually, and then discuss in class. The individual reflections mostly were summarized in written forms, but also mentimeter-based systems[6] was used. Example of statements follow:

- I think the chosen set of the SDGs is a good representation of how we shall approach sustainable development.
- Computer Science and Software Engineering is absolutely necessary to approach the SDGs.
- The UN is the best-suited organization to be responsible for global issues.
- In my home country, I feel that there is an awareness of the importance of sustainability at large!
- At a personal level, I live a sustainable life.
- Water is clearly the most important sustainability issue.
- IT-based systems could clearly contribute to waste-management, a clean city, and a clean environment.
- All the SDGs are clearly interconnected.

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[3] Hedenus, Fredrik, Persson, Martin & Sprei, Frances (2018), Sustainable Development – Nuances and Perspectives. 1 edition. Lund: Studentlitteratur (140 p).

[4] Lässig, Jörg, Kersting, Kristian & Morik, Katharina (Eds.) (2016), Computational Sustainability (Studies in Computational Intelligence Volume 645). Cham: Springer International Publishing (276 p).

[5] Oates, Briony J (2006), Researching Information Systems and Computing. London: Sage Publications (360 p).

[6] Engage your audience & eliminate awkward silences, https://www.mentimeter.com/

- Self-reflection tests like this clearly contributes to higher levels of maturity when approaching projects with sustainability themes.

It was made clear from the teacher that the students should feel free in their approach to the statements, and not give answers that they think the teacher expected.

Finally, the course focused on a design project, where the main theme for the project was decided upon by the teacher, that is, SDG 11, on *Sustainable Cities*. The choice of that SGD was based upon the inherent complexity of that SDG and that it may be dependent on further SDGs. Still, it was up to the students to take further focus initiatives within the frames of *Sustainable Cities*. A demand was that the students should come up with IT-solutions to an observed problem and design an IT-based architecture that solves the problem. A report shall conclude the project, with a presentation within the class.

2.2 Project in Multidisciplinary Contexts

The course[7] is focused on a main aim of '*design and implementation of projects in multidisciplinary contexts and concepts and techniques for implementing projects in research contexts*.' To meet that aim, student projects have been grounded in applied research projects involving researchers at CS@HKR, where contributions can be seen in contexts of SD. Examples of such research projects include:

1. *Identifying bacteria in drinking water*. The project has involved Microbiology researchers at Lund University[8], as well as representatives of the Ringsjöverket Drinking Water Treatment Plant[9]. The project clearly connects to SDG 6, on *Clean Water*.
2. *Identifying cancer cells in blood samples*. The project was guested by researchers in Bioanalysis at HKR. The project connects to SDG 3, on *Good Health and Well Being*.
3. *Identifying cases of cracks in concrete of bridge fundaments*. The project was connected to Öresundsbrokonsortiet[10], that manages the bridge between Sweden and Denmark, and relates to SDG 11, on *Sustainable Cities* (there is no *Sustainable Regions* amongst the SDGs).
4. *Analyzing movements of mallards in local areas*. The project has been guested by researchers in Environmental Science at HKR, and relates especially to SDG 15, *life on land*.

The projects, that are chosen by the teachers, are conducted through iterative project meetings, where students are guided further through the process of fulfilling their projects. The course ends up with a final presentation by the students, and a final written report. To solve the project problems, the students need to apply techniques

[7] Project in Multidisciplinary Contexts - 9 credits, https://www.hkr.se/en/course/DT586D/course-syllabus
[8] Lund University research Magazine, http://www.researchmagazine.lu.se/2016/02/17/our-drinking-water-pipes-are-teeming-with-bacteria/
[9] Sydvatten – collaborating for public welfare, https://sydvatten.se/app/uploads/2023/04/Verksprocessr_eng_fo%CC%88r-hemsidan_2023.pdf
[10] Øresundsbro Konsortiet, https://www.oresundsbron.com/en/about-oresundsbron/about-us/oresundsbro-konsortiet

of courses learnt at the previous semester. Thus, the course lives up to aims for SD, Computer Science research themes, as well as multi-disciplinarity.

3 RESULTS

A program evaluation was conducted by representatives of CS@HKR in 2021, to get an overview insight in students' attitudes towards the program. On a five graded scale, students responded to statements regarding different aspects of the program, where 5 corresponds to the most positive attitude, and 1 to the least. Overall, the students responded very positively, with a mean value over all students and statements of 4.75. A 5 was given to statements, such as, '*The programme syllabus has corresponded well to the actual content of the program'*, '*I have acquired insights about research in many subjects that were covered in the courses'*, and '*Communication with the teachers has worked well in general'*. The lowest value, 4.25 was given to '*I feel that the program content and structure give me good opportunities to get jobs in the IT-sector (programming, consulting, development etc.)'.*

Moreover, all university programs shall be evaluated in regulated ways, including this master program. In 2022 an evaluation of the program was conducted by HKR-internal, as well as external evaluators, from academia and industry. That evaluation concerned both organizational and program-structural aspects and showed a general satisfaction with the program. Criticism and potentials, pointed out though, concerned more industrial contacts with the region's industry, and a strive after a second master year. The most critical point regarded how to attract larger groups of students. The program has suffered from small groups of attending students. Very few of the students at the department's bachelor level show interest in continuing at the master level, the students of the program are mostly attracted internationally.

To meet the criticism regarding contacts with the region's industry, representatives from such contexts will be invited for guest lecturing. It is here considered valuable that such lectures not only present technical aspects of interest, but that those also should have interesting points of connection to the study program with respect to contexts such as SD or the Fourth Industrial Revolution. What was possibly not highlighted during the evaluation was that several of the degree projects were actually done against companies. This also creates opportunities for the students to be employed after graduation, and for the international students to remain in Sweden, which several of them seem to want.

To meet the critical matter of low student enrollment, a more offensive, but still gentle, strategy has been introduced. Applying students have been contacted, and will be contacted continuously, and provided with information regarding the study program, how to live and act in Sweden, and more. The students will be treated as if they already have accepted to take part of the program. Of course, they still have their own free will in their final decisions.

At levels of courses, course evaluations have shown satisfactory results, with the latest mean values provided by students (same scale used as pointed out above), autumn 2022 of 4.4 for the 'methods-course', and spring 2023, of 4.3 for the 'projects-course'. Qualitative judgements include:

- The Methods-course:
    - *I learned a lot from this class. This class allowed me to systematically understand the relationship between sustainable development and computer science, and also exercised my reading and writing skills.*
    - *It is good to know how the computer science is contributing for sustainable goals to make the world a better place to live and the way think to achieve the sustainable goals 2030 is quite motivating and challenging too*.
- The Project-course:
    - *Through this course, I learned how to work in small groups to complete a project. And the projects that this course focuses on are also very interesting. Not only did I learn about technologies such as data processing and machine learning, but also the living habits of some species of ducks, etc., which are very in line with the topic of sustainable development.*
    - *The project meeting we had with guests in middle of the course with guests from environmental department and some faculty from science department it would have been better we have at initial stage*

Getting back to the self-reflecting training of the exercises, as mentioned in previous section, a more comprehensive study on this has previously been made by the author of this contribution and presented at a faculty meeting. It is outside the scope of this paper to dig more in the details, but what is interesting is that students mostly have been positive towards this kind of exercise, which is also shown through positive responses towards the statement '*Self-reflection tests like this clearly contributes to higher levels of maturity when approaching projects with sustainability themes*.'.

An interesting question concerns what happens next with the students. While [8] in first place is addressing how to prepare the university's educators towards effective teaching regarding SD, that report also points out a need for investigating what happens with the students after their education. That is, how do they contribute to future society with respect to SD? Currently it is well known that the students are highly employable, some even continue their careers in academia. Still, the explicit information on the impact by the alumni on SD is rather vague, and as pointed out by [8], clarifying on this is a both interesting and important potential future work.

4 SUMMARY

To sum up: the author of this paper was initially engaged when the SDSN NE was launched and saw an interest in contributions from the field of computer science to approach the SDGs of the UN's Agenda 2030. Furthermore, the author was engaged in investigating proposals on how to meet the criticism towards the home university's lack of ways to manage SD at different levels. One of the proposals addressed a course for educators to guide them in teaching-learning for SD. The involvement in the creation of such a course provided a piece of the puzzle to complete the design

and implementation of the revision of a master's program. In that program, computer science students are given the potential to contribute as future agents of positive change.

This paper has reported that the program works well, both at program level and in the courses presented. The students have generally shown interest and satisfaction both in relation to computer science and SD.

In program evaluations, it has been suggested that further work towards industrial contacts is seen as valuable for the program, as well as a striving towards a two-year master programme. A critical problem that the current program has, though, is the low number of attending students, which has caused the program to be questioned and in need of further revisions.

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