# Using Climate Research to Introduce Sustainability in a Computer Science Curriculum

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***Abstract*—As challenges related to global climate change become ever more pressing, it is imperative that all parts of higher education are capable of preparing students to deal with global challenges posed by climate change in their professional careers. Many study programmes in engineering have attempted to introduce sustainability as part of their curriculum, but there are many factors that may impede progress and uptake, both within faculty and among students. Especially Computer Science education has been slow to adopt sustainability in the core curriculum. Those who have introduced sustainability as a separate subject have reported generally lower student ratings, especially if students fail to see the relevance of sustainability for them. To address these issues, we describe an approach to use concrete climate simulation tools and data to introduce computer science students to sustainability-related topics. The main aim is to improve students' appreciation of, and interest in, sustainability issues by using real-world sustainability problems, hard data and technical methods. Also, we wish to assess whether common course material, available as an open toolbox, can lower the barriers of entry for educators who wish to introduce sustainability in their own computer science courses. In this paper, we describe a toolbox with climate change research tools and simulation data, and report on experiences from two courses and three student groups where this material has been used. We describe some impediments and success factors to using the material, and present the results of surveys and interviews from the three student groups participating.**

Our public understanding of the full impacts of climate change, including radical loss of biodiversity, disruption of food production and mass migration to name a few, has made climate change an important topic in public discourse.[1] Climate change is no longer a topic restricted to discussions at climate science conferences or in environmental groups, but a common part of public discourse. It is increasingly obvious that challenges ahead will require not only small, incremental improvements to current ways of producing goods and services, but more significant changes in general. The challenges that we face ahead are stupenduous, and will require significant efforts by all members of society, as individuals as well as professionals. The UN has specifically mentioned education for sustainable development as a key to enabling societies to cope with challenges ahead. [2]

## I. Sustainability in Higher Education

Education for Sustainable Development (ESD) has seen an uptake in academia, and increased interest in integrating issues related to sustainable development into the main curriculum. From having been a topic reserved for special degree programmes in environmental studies, several attempts have been made to integrate sustainability into the main curriculum of a broader set of degree programmes such as in computer science (see, e.g. [3], [4]).

Although some argue that the education system need to be radically revised in order to fully enable students to become change agents for a sustainable society [5], [6], others outline models for integrating sustainable development in curricula that do not require radical departures from what we mean by higher education [7]. Just as with other approaches to introduce new topics or aspects in education, it is critical to ensure that students feel motivated to participate in whatever activities we subject them to, and demonstrate the relevance of sustainable development for them [7]. Barth describes three central starting points for selecting material on sustainable development for integration into students' curriculum:

1) Students must appreciate the relevance of sustainable devlopment for their studies as well as their future careers and lives,
2) they must feel that they are active in making the very decisions that will determine whether future societies will become sustainable, and
3) they must understand how they can apply their domain-specific problem-solving techniques on problems related to sustainable development, through general principles or concrete tools and methods.

Commonly, there have two types of obstacles to implement sustainable development in study programmes other than environmental studies: the "not our subject" and "crowded curriculum" objections. As sustainable development can be argued to concern everyone and no-one at the same time, educators have found it difficult to relate to the issues, and find that they are important for their own curricula. To improve the relevance of the subject to all students, we could try to apply existing problem-solving techniques from engineering on large-scale societal problems. Doing so in a curriculum that is already full with "core" courses presents several challenges, both cultural challenges and economical. One approach to improve student appreciation of sustainable development, and to lower the barrier for educators, might be to use a common set of educational resources on sustainability-related issues and

include those resources in several different courses at a lower marginal cost. For instance, at KTH, Sweden, a collection of sustainability learning material has been developed that can be adapted for different courses in which the material is used [8].

## II. Sustainability in Computer Science

In Computer Science, educators have only recently developed their own understanding of what it would mean to integrate sustainable development in the curriculum. For instance, Penzenstadler argues that it is important to distinguish between the environmental effects of producing and using any IT system, and the potential effects that IT systems may have in a larger scope, where our ability to solve sustainability problems improve as a result of moving from a product-oriented economy to one built on services [9]. One way to develop a positive attitude towards using professional skills in solving sustainability issues is to help students see how their skills can be applied to addressing sustainability-related issues [4].

At Linköpings universitet, we have conducted a project in which students from several degree programmes, in two courses: one in their first year, and one eligible in the fourth and fifth years, have worked on projects related to understanding the impacts of climate change. Students have been given climate simulation data from regional 100 year simulations of mean temperature and precipitation levels in Europe, and use existing tools to extract meaningful patterns from that data. The first-year students have been tasked with running some small scripts to understand how programming skills can be relevant when working as a researcher in climate science research, conduct a visit at the climate science research facility (SMHI in Sweden) and write a longer report on climate science research in general, with examples of how to use tools they have studied. Students in the course for fourth and fifth year students were given a task to provide information visualization tools for different groups of users based on the same types of climate simulation data. In both cases, students had to do research independently on climate change, climate simulations, and climate research. The purpose of using climate models and simulation data was to make them feel engaged in climate science as professionals, and see the effects of using their knowledge to address problems in climate science research. Engaging students in sustainability topics and make sure that they are active in directing their own learning has been regarded as key to enable students' to actively contribute to a more sustainable society [10].

## III. Results

The course material was developed in collaboration with partners at the Swedish Meteorological and Hydrological Institute (SMHI) and took less than a week to assemble with their help. This enabled us to focus on how to help students actively engage in using the material, and how to search for new information that they would need in their projects.

After their courses, students were asked to fill out a short questionnaire, and participate in interviews. Nine students answered the questionnaire, and 2 students participated in interviews.

| **Question** | **Mean answer (from 1 to 5)** |
|---|---|
| Q1: How important for the course was the use of climate models? | 2.22 |
| Q2: How important was it to you that climate models were used as the objects of study? | 2.56 |
| Q3: How was your experience of the course affected by the use of climate models as the object of study? | 3.67 |
| Q4: How important is it to you that technical courses give examples of applications related to sustainable development? | 4.0 |
| Q5: Has your understanding of climate change been affected by the use of climate models and climate data? | 4.0 |
| Q6: Do you consider the effects of climate change more important now? | 3.56 |
| Q7: Are you more willing to consider working professionally with problems related to sustainable development now? | 3.11 |

TABLE I
Answers to survey questions on attitudes towards climate change

### A. Survey

In table I, survey results give us an indication of students' impressions of the use of climate models (N=9). Among the answer alternatives, 1 was always the "negative" answer, such as "not important" or "not improved", and 5 was the positive answer, such as "very important" or "much improved". Students were in genereal positive to the use of climate models, and found it very important that technical courses include applications related to sustainable development. Somewhat paradoxically, they did not consider it *important* for the courses per se, which may be due to the expectations that courses are not advertised as being *about* climate change. Interestingly, students claimed to have learned much more about climate change in general, although only very little direct material was developed for students on learning about climate change. It was required of them to understand more on the subject to write their reports and develop their visualization tools, though.

### B. Interviews

Two interviews were conducted after the surveys, with students from the first-year course. Both students were asked to expand on their thoughts from the survey, and were asked questions specifically on whether they believed this had an effect on their attitudes towards working on sustainability-related problems in general, or climate research in particular. They were given the opportunity to answer both for themselves, and how they believed that members of their groups

had reacted to the use of climate models and simulation data. Here, I refer to them as students A and B. Student A was a male student, and B a female student. As a general distinction between the two, A claimed not to have understood the full implications and scope of climate change before, and said that his understanding had improved much. Student B on the other hand, described herself as well aware of not only climate change issues, but environmental issues in general. Student A reflected on how his improved knowledge of climate change and climate research had changed his attitudes towards climate change issues: "Before, I thought that people who talked about climate problems were extremists because their proposals were so extreme, but I don't think so anymore". However, he would have liked to spend more time on programming in their project, and was still more interested in the technique to be used, than in contributing specifically to solving problems related to sustainable development: "I think it would have been more interesting if we had had building blocks for analyzing [climate simulation] files and that I could have said 'I produced this' after the project". On selecting courses or projects based on the use of sustainability topics, he was more focused on whether courses would make use of interesting types of techniques for solving problems: "I would rather look at the technique used in the course".

Student B felt that the use of climate models opened up new perspectives on what they could engage in as engineers: "It was an eye opener that IT is more than we may have first thought". The technical nature of some of the material led to difficulties, as they had no training in programming and the use of scientific software: "We had no previous proficiency in programming so it was difficult to start". However, as side effects of their project, they had discussions on climate change in general and started discussing the topic and sharing material: "Several talked about Cowspiracy and other documentaries, videos on Youtube and the discussions were about the effects of climate change".

## IV. Discussion

With only little direct material, and no formal requirements on the students that they should consider the direct effects or importance of climate change, the assignments given still stimulated discussions among students and generally improved their appreciation of the nature and importance of climate change and climate research. On its' own, these activities and projects are probably not enough to help students become fully productive engineers for sustainable development, or indeed change agents in the workplace as they did not show a strong interest in working with sustainability-related issues in their later courses. However, the project has thus far demonstrated that CS courses can benefit from using applications related to sustainable development to show how techniques from students main curriculum can be applied to real-world sustainability issues, and students are eager to learn more, and would like to see more examples of how to apply their skills for sustainable development.

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