ICT4S Reaching Out

Making sustainability relevant in higher education

Elina Eriksson and Daniel Pargman

School of Computer Science and Communication
Centre for Sustainable Communications
KTH Royal Institute of Technology
Stockholm, Sweden
elina@kth.se, pargman@kth.s

Abstract— **Many media technology and computer science engineering students suffer from the preconceived opinion that sustainability is at best peripheral, and at worst irrelevant to their education. In this paper we discuss our experiences of integrating sustainability and ICT4S into a media technology engineering programme. An overarching tension has been in finding a balance between teaching about sustainability in general, and teaching about ICT4S in particular. Furthermore, what aspects of the wide and interdisciplinary area of ICT4S are most relevant to teach to media technology students, and how can the connection between ICT and sustainability be "refined", clarified and expressed? We explicate how we have gone about to shape the course in such a way that it becomes both relevant and possible for these students to relate to it, and we exemplify with choices made, of which one had been the implementation and adaption of the GaSuCo board game. While the results presented here are primarily relevant to media technology and computer science educations, we also conclude with recommendations to the larger ICT4S community. We argue that the ICT4S community does not only need to take part in developing education in this area, but also needs to *conduct research* on how to educate students in ICT4S.**

Index Terms—**Higher education, ICT4S, sustainability, media technology, engineering**

I. Introduction

There is unequivocal evidence that the world's mean temperature has risen and that we are now facing anthropogenic climate change [1, 2]. Climate change is however not the only problem we face in the age of the anthropocene [3] - we are also facing problems relating to resource scarcity [4, 5] as well as in general pushing against or overstepping several planetary boundaries [6]. In this world of ours, ICT (Information and Communication Technology) has become increasingly more important as it permeates many of our daily practices up to the point that some argue that it has become "the fourth utility" after heating, water and electricity [7]. ICT has become fundamental to how we live our lives today, but it unfortunately also has some negative impacts due to greenhouse gas emissions, resource depletion [8], and e-waste [9]. Despite this, ICT is often considered to be a promising and potentially transformative technology in that ICT-enabled solutions can substantially reduce greenhouse gas emissions in other areas such as the power sector, transportation, agriculture and land use, buildings, manufacturing and in the consumer and service sector [10]. This implies that ICT professionals have an important role to play in shaping the future, both in terms of dampening negative, direct ("first-order") effects of ICT and in strengthening positive, indirect ("second-order") effects [11]. It thus also follows that the ICT4S community ought to care a lot about, and direct a certain part of its energy towards the question of how to educate the future professionals who will work in the field for decades to come. This rationale is the underlying reason for why we, in this paper, turn to education and to the question of how to integrate ICT4S into undergraduate education programmes. We will below describe our experiences of teaching ICT4S to media technology engineering students - one of many student groups working with ICT. For these students, sustainability is not a central topic in their education and we will discuss how we have gone about to teach sustainability in such a way that it becomes relevant and possible for these students to relate to. We will exemplify by discussing some of the choices and efforts we have implemented in our course so as to make it more targeted at and engaging for this group of students.

II. ICT4S - Integrating sustainability into the ICT education

What strategies could be used when integrating sustainability into an existing higher education educational programme? Mann et al. [12] describe three main approaches to integrating sustainability in higher education; a centralized approach, a distributed approach, and a blended approach. With the centralized approach, the topic of sustainability is concentrated to one or two dedicated courses. It could very well be that this is a less effective, albeit easier way to implement sustainability into the curriculum [12]. In a distributed approach, sustainability would instead be addressed across the whole curriculum, in several courses, and a blended approach would imply both dedicated specific courses as well as activities and modules that are integrated into the rest of the curriculum. Distributed and blended approaches probably have

a greatest impact, but they are more difficult to implement since they presuppose, and indeed perhaps require, common ground, consensus and cooperation between many educators within a programme [12].

Cai [13] presents a set of strategies that partly overlaps with Mann's approaches; 1) developing a new course, 2) using a modular approach to integrate sustainability into several different courses, and finally 3) an "integrative and transformative" approach. The first two strategies resemble Mann's centralized and distributed approaches, but the third strategy is instead based on a complete re-design of (some) computing courses with sustainability as the main goal [13]. Sterling [14] gives a more ample account of the transformative approach, where he argues for a fundamental redesign of the entire educational system, with a sustainable society as the main focus and goal, and where "transformative learning" is supported. This would require a change of paradigms including the reform of both epistemology and praxis in higher education, and where "the goal of all education would be sustainable development, and the different disciplines and subjects would all contribute to it" [15, p. 223]. Even though a transformative change might be preferable or even turn out to be a necessity in the future, such a change is not easily accomplished within the current educational system.

It is most certainly the case that at this point in time, only a minority of the ICT-related educational programs have managed to adopt Mann's [12] distributed or blended approaches, or for that matter Cai's [13] and Sterling's [14] "transformative" strategies. The current level of integration of sustainability into our media technology curriculum is currently restricted to one dedicated course, and we have earlier discussed how to make the most of that course, using it as a platform to maximize the impact on the students' awareness of and their thinking about sustainability issues [16]. In the following text we will first present the course and the empirical material that this paper is based on. We will then describe some of the choices we have made in terms of connecting the topic of sustainability to ICT, in order to make sustainability relevant and possible, for the students in question, to relate to.

III. The course

The concrete examples and results presented in this paper stems from the planning and teaching of an English-language course, "DM2573 Sustainability and Media Technology", at KTH Royal Institute of Technology in Stockholm, Sweden. The course is 7.5 ECTS, which corresponds to 12.5% of the total course load for an academic year. The course is given at 50% pace during a quarter of the academic year, i.e. most of the students will read one other course in parallel.

KTH Royal Institute of Technology in Stockholm, Sweden, has around 20 Master of Science in Engineering programmes and the School of Computer Science and Communication has offered a Master of Science in Media Technology since 1999[1]. The Master of Science in Media Technology is primarily

directed towards educating engineering students for jobs in a labour market around traditional mass media (publishing, radio, TV, film) and new media industries (human-computer interaction, interaction design, computer games, social media and in general anything related to the Internet). Alumni from the program have founded the successful companies Soundcloud, Prezi, Videoplaza, Jaycut, Ocean Observations and Readmill [17].

While one of the authors have taught courses in the programme for more than a decade, this course in particular is a more recent addition and the brunt of the effort to plan the course was made during the first half of 2012. The course has since then been taught twice. The incentive for giving the course originated from an executive decision establishing that all KTH engineering programmes *must* have at least one course in "sustainable development". Stating this for a fact was also a way for KTH to comply with the Swedish Higher Education Act. The Higher Education Act has several requirements that can be related to sustainability and that students must fulfil as part of a degree of Master of Science in Engineering.

IV. Empirical material

The empirical material in this paper consists of different qualitative and quantitative data that have been collected during the two years that the course has been given. This includes a variety of data where some is the same as when giving any course, e.g. hand-ins, exams and course evaluations. We have furthermore conducted observations during gaming sessions (see below) and semi-structured interviews with 5 students, as well as carrying out mid-course questionnaires (besides the final course evaluation). Lastly, we conducted so-called "gripe sessions" (public course evaluations and discussions) at the end of the course. Notes were taken during the observations and the interviews and the interviews have also been recorded.

V. Which Sustainability and what ICT?

Having acknowledged the need for future ICT professionals to learn about ICT4S, we turn to the issue of discussing what this entails. The ICT4S community is still young, and what exactly constitutes ICT4S can in itself be debated [18]. Turning to the concept of sustainability in ICT4S, we meet a multifaceted concept with several different meanings and definitions [19, 20]. Depending on the definition chosen, emphasis can be put on different aspects of sustainability as well as different aspects, functions and uses of media technologies and ICT.

We have chosen not to emphasize one particular definition of sustainable development in our efforts to integrate sustainability into the media technology education. Instead, we present different possible definitions and perspectives such as the Brundtland report [21], the planetary boundaries model [6], Heinberg's five axioms of sustainability [19] and Grigg's six sustainable development goals [22] as well as the notion that sustainability is "a process of continuous adaption, of perpetually addressing new or on-going problems and securing the resources to do so" [23]. Aside from these different perspectives on salient and important characteristics of

---

[1] See further: http://www.kth.se/en/studies/programmes/swedish-programmes/msc/media-technology-300-credits-1.63132

sustainability, we have in our course primarily emphasised climate change (which have been prominent in public debates not the least because of the high-profile IPCC reports [1]) and limited supplies of non-renewable resources (rare earth metals, oil and other fossil fuels etc.) [24]. Climate change has not only been cast as a highly present and pressing problem in media, but also has the pedagogical advantage of being connected to relatively clear goals in terms of reducing greenhouse gas emissions. An emphasis on climate change and resource scarcity does not mean that we ignore issues of social and economic sustainability, but it is a fair assessment to say that these topics are less central to this particular course.

The first part of ICT4S, e.g. Information and Communication Technologies (ICT), is an increasingly elusive concept, encompassing many types of technologies connected to the handling, distribution and communication of information. ICT professionals are nowadays educated in many diverse educational settings ranging from electrical engineering, computer science and software engineering to human-computer interaction and media technology. Lending from the most central of ideas in user-centred design [25-27], we need to carefully consider how we should teach ICT4S to fit this particular group of students. We should not only consider the knowledge and skills that these future ICT professionals require, but also match the content to what they will be able to understand and relate to in their present lives. The students in question are not mainly involved in coding or software engineering, or for that matter in hardware development, but rather in the design of concepts, interfaces and media content, including social media. How then have we shaped the contents of the course to "reach" these students and help effectuate transformational change?

VI. Adaptation efforts

In a previous paper [16], we discuss the tension between teaching issues pertaining to a) sustainability and sustainable development in general and b) ICT and sustainability in particular. There is no clear-cut answer as to how to create an optimal balance, but we do argue that in order to make the subject relevant for our students, sustainability positively has to be as tightly connected as possible to their own domain. If it doesn't relate to other subjects areas in the education, or topics that the students in question take an interest in, it can easily become (yet another) course to "get through" and "tick off" without it having any measurable impact on the students' thinking or their future actions as ICT professionals. Below we describe two specific efforts of connecting the topic of sustainability to this particular group of students and to our (their) perspective on media technology and ICT.

A. ICT and climate change

We have made the choice in our course is to primarily focus on environmental sustainability and climate change rather than on social or economic sustainability. As explained above, one reason for this is the strong presence of this kind of framing in media and in the students' subsequent familiarity with that particular framing of "the problem of sustainability". The connection between, on the one hand carbon emissions (and

other greenhouse gases) and, on the other hand climate change is also at least passingly familiar to almost all students. There are simple tools available on the Internet for converting CO_2 emissions to other units that are more easily understood [28], but, the premier question for us is how to clearly connect ICT to CO_2 emissions for our students and in our course. In this we have chosen to use energy and electricity as intermediary concepts, e.g. ICT uses energy (in the form of electricity) and energy use has effects on carbon emissions (and climate change), e.g.: ICT ← electricity/energy → CO_2/climate change.

This conceptual model makes it possible to connect ICT industry (for example data centers) or ICT everyday use to energy and carbon emissions. However the connection is, for many students, still tenuous and hard to understand on an intuitive level. Most students don't have the same "natural" (intuitive) understanding of energy and power (energy/time unit) as they for example do for distance and speed (distance/time unit). We have come to understand that something more is necessary to bring home a deep and personal understanding of these issues and we have chosen to use the concept of "energy slaves" to do so[2].

In short, an energy slave corresponds to the energy necessary to replace the (muscle) power of one human worker. Energy slaves play in the same league as the "horsepower" unit of power, but where a horsepower is approximately equivalent to ten (human) energy slaves. According to Avallone et. al. [29], a well-fed labourer can produce an average output of 75 watts during an 8-hour day, i.e. 600 Wh (0.6 kWh) per day. This calculation is also in very much in line with McKibben [2] stating that one barrel of oil (159 litres) is equivalent to 25000 hours of human labour. If, as the Greek philosopher Protagoas stated, "man is the measure of all things", then the concept of energy slaves makes sense as well as making it much easier to get a feeling for, and for engineering students to start to make calculations about the energy consumption of ICT industry (data centers) or everyday ICT and media technology activities (such as using a large flatscreen TV, a laptop or a smartphone as well as the energy costs for sending an email, do a Google search, reading a webpage or playing an online game).

B. Values and adapting GaSuCo[3]

Although some aspects of sustainability are grounded in scientific facts, many other aspects, including future-oriented ideas, are inherently value-laden and normative. How can we approach these questions and include them in our education without becoming too ideological - a problem that has been identified as one of several challenges remaining within education on sustainable development [30]. In our case, we decided to include activities in the course that encouraged, or even forced students to discuss difficult topics, letting them explore values and normative issues relating to sustainability.

One such structured activity was the board game GaSuCo [31], a learning game specifically designed to stimulate small-

---

[2] The term "energy slave" was coined by R. Buckminister Fuller and used in the "World Energy" Fortune Magazine February 1940 cover illustration (see http://www.fulltable.com/vts/f/fortune/xb/50.jpg).

[3] http://gasuco.com/home-eng3

group discussions on complex sustainability issues. The game has a general orientation to sustainability and we felt it was necessary to adopt the game to an ICT and media technology context for us to be able to use it within our course. In cooperation of the game designer, we translated the game to English and included questions that specifically targeted ICT and media technology topics. In our aim to make the new questions (pertaining to ICT and media technologies) as relevant as possible to the students, we chose to (re-)use the students' own questions. We more specifically turned to the questions that students had submitted for seminar discussions during the previous year[4] and identified open-ended questions that had a high potential for stimulating fruitful discussions relating to ICT and media technologies. We had to develop or rephrase most questions, but some were possible to include with only minor alterations. A few examples of ICT and media technology-related questions that were included in our specific edition of the game are:

> *Do you think the media covers the climate change issue satisfactorily?*

> *ICT can help us share physical products, for example in the form of car pools. What else can be shared with the help of ICT?*

> *Should we all adopt cloud computing for sustainability reasons? Elaborate!*

> *Is it sustainable to have free Internet services (mail, twitter, facebook etc.)?*

> *Do software developers have a responsibility to consider hardware requirements when they develop software?*

> *If there are major changes in our world due to climate change or lack of resources, how will we prioritize ICT compared to other infrastructure (healthcare, transport, education etc)?*

The one factor that these questions have in common is that there are no easy answers to them. The purpose of including "difficult" questions such as these is to start the course by having the students wrangle with these questions together, in small groups. The questions we developed were included in the decks of more general questions about sustainability that already existed for the game. In our edition of the game, three quarters of the questions relate to sustainability in general and a quarter relate to ICT and media technologies in particular.

---

[4] Each student had to propose one question in advance before each seminar (once per week). This meant we had literally hundreds of questions to choose from.

VII. Outcomes

In general the students are fairly content with the course contents and with learning more about sustainability. However, in the formal course evaluation (which 38 out of 60 students answered), 44% of the students found the course meaningful or very meaningful as part of the media technology programme while 39% found it less meaningful or not at all meaningful - a somewhat discouraging result. Since a lot of energy and thought had gone into the planning and execution of the course, we wondered why. Elaboration about the meaningfulness (or not) of the course can also been seen in the open ended comments in the course evaluation:

> *I enjoyed the course. I think it is meaningful and I learned a lot. But there could have been [a better] connection to media technology. I think it was too much just about CO_2, etc. More like a general sustainability course. I wanted more past/present examples of media technology solutions to the problem, more discussions and how or what we can do as media technology students*

This might, on the surface, sound like a quite negative comment, but it can equally well be interpreted as a positive comment, urging us (teachers) to boldly march forward and integrate ICT and media technologies into the course to a higher extent than we presently do, i.e. we're on the right track but we don't go far enough.

We have also asked the students what their relationship to sustainability is, with predefined answers ranging from "Indifferent" to "I am engaged and I act!". This question was given to the students both when the course started as well as when it was winding down (in the course evaluation). The results show that the students' perception of themselves moved from just being "concerned" to becoming more engaged, and that they perceive themselves as acting more in accordance with what they believe is sustainable at the end of the course. At the end of the course more students chose to use the option "other" regarding their relationship to sustainability, and these students proceeded to, in their own words, state exactly what their relationship is. Answers mostly came down to the students explaining that they were trying to do as much as they can:

> *I'm concerned and try to do a much as possible for me at the moment.*

> *I am concerned and I will try more to change my behaviour for the better*

> *I buy as much organic as I can, I eat vegetarian, I recycle whatever I can, I have an 'environmentally friendly' utility company ... I am concerned, but I feel powerless as I am so tiny in this world.*

Students' self-perceived relationship to sustainability issues do not necessarily correspond to actual behaviour, but the course seems to have changed their perspectives on, and their view of their own role in relation to sustainability. They exhibit

an increased need to state and explicate their own behaviours, which as a minimum suggests that they have thought about the issues at hand and more consciously had adopted a stance. The results further suggest that we were not fully successful in connecting sustainability to ICT and media technologies, but that the course had engaged the students on a personal level.

In the open-ended parts of the course evaluation, and during the very last course seminar, students voiced a wish to find more ways to act, and to do so especially within the field of ICT and media technology. From this we draw the conclusion that it would be desirable to find and provide more numerous, *concrete* examples of how ICT and media technologies can be used to work towards sustainability, as well as including more hands-on work in the course. It would however be equally possible to argue that this implies a need to integrate sustainability into *the rest of the curriculum* for the engineering programme. Another alternative could be to help students vent their concern by pairing them off with (for example) non-profit organizations in the area that would benefit from their enthusiasm and knowledge (in, for example, web design). One student pointed at the discrepancy between the aims of this particular course in relation to the rest of the media technology programme:

> *I got the impression that the course and the course leaders' goal were to raise awareness among the students. While that is a great cause and it certainly worked on me, I am not sure if that is enough to make it fit into the masters program for media technology students. I thought the structure made it hard to apply anything I've learned in other courses to the course material. The other way around, parallel to this course I read another course about making user friendly apps and just felt very negative toward making useless energy demanding apps. So this course have not really helped me understand how to be more sustainable in my work as a media technology engineer but rather made me question the whole moral of creating digital media. I am not sure how to feel about that and thought you should know.*

The aim was not to discourage the students from becoming media technology engineers, but rather to make them think critically and reflect on the outcome of their work, for example when designing new technologies. It would appear that we have been successful in fostering critical thinking in the students, but less successful in outlining a clear path as regards to applying their newfound knowledge ("convictions") to their professional area. It might also be the case that there *does not exist* any such "clear path" and that we all - teachers and students alike - individually and collectively have to *invent* such a path. We should however try to become better at encouraging the students to apply their skills and their passion by presenting positive examples of how ICT can be used to reshape society to become more sustainable.

Based on answers in the course evaluation it seems we were successful in making the connection between ICT and climate change in our course, but less successful in honing our students' abilities to calculate and get a feeling for energy and work (in both humans/energy slaves and in machines/the internal combustion engine for example). This became apparent when the exam was to be corrected, and some of the students also mentioned this in the course evaluation and asked for more practical seminar exercises centred on calculations instead of (only) readings and discussions:

> *I would like the seminars to include practical things like calculating and doing life cycle analysis of products.*

> *The discussions at the seminars were interesting, but I thought there were too many of the same kind. The last one or two did not add that much. It would have been wiser to spend that time on some task or small research or calculation. One seminar could also have been conducted as a study visit to some company who has done something great for their energy reduction or to some water research lab or likewise.*

The board game GaSuCo was used in three gaming sessions[5] in the very beginning of the course, where students groups of 3-4 students played together. We worked towards changing the composition of groups at every gaming session, encouraging discussions with new peers each time (instead of repeated discussions between friends). The purpose with the game (and the lectures) was to introduce various aspects of sustainability to the students and to nurture an open discussion climate. The usage of the board game GaSuCo has been evaluated through observations during the gaming session, a post-game questionnaire as well as through semi-structured interviews with five students. In general, the game was very much appreciated by the students and it was considered to be a very good start of the course. A few students found the game boring, or felt that the discussion in their particular group had not been very stimulating. We did, on the other hand observe that many groups spent more than the allotted three minutes (as determined by small hourglass that is included in the game) on each discussion topic. Several groups also kept on playing even after they were allowed to quit (because time had run out). The interviews clearly showed that the students had noticed the presence of questions concerning ICT and media technologies in particular:

> *Interviewer: Did you feel that the game was connected to your own subject - media technology?*
> *Respondent: Yes, in the questions that concerned ICT to a high degree.*
> *I: Which question did you like most to discuss; the general questions on sustainability or the ICT related questions?*
> *R: The questions that were connected to ICT led to better discussions. It's a subject most [of the students] are familiar with.*

---

[5] The gaming sessions were integrated in a module with a lecture followed by a gaming session, followed by a lecture etc.

Since the purpose of the first part of the course was to introduce sustainability to the students, a major part of the discussion topics in the game treated sustainability at a more general (non-ICT4S) level. Evidently the students preferred the ICT-related topics, and one could argue that these should be made more numerous in the game (at present they constitute 25% of the questions). This is however a balancing act, since if we introduced more ICT and media technology-related questions, the student would on the other hand not get the same understanding of the (enormous) scope of the topic of sustainability. We are however satisfied with knowing that the questions specifically pertaining to ICT and media technologies managed to engage the students in the larger topic of sustainability.

VIII. Discussion

In our effort to integrate ICT4S into a media technology engineering programme, we believe we have been successful in engaging the students on a personal level, and in encouraging them to think critically about the sustainability topic (which by no means necessarily comes naturally at a school of computer science). However, the results suggest that the students felt that they did not learn enough about actions or actual hands-on skills that could be connected to sustainability, and that, in the end, the topic (sustainability) was not sufficiently connected to media technology and ICT (despite our efforts). There are several reflections in relation to these observations:

The first is that even though the course falls within our own fields of expertise and an area where we do research, we still had some trouble exemplifying and connecting sustainability to the students' worldviews. While it is not unusual to have courses pertaining to sustainability and sustainable development in engineering programs, it is less usual to have such courses in media technology and computer science programmes. Furthermore, it is even more unusual to "insource" such courses, i.e. the most common solution is instead to have some other department take responsibility for developing and teaching such a course. While there are obvious advantages to having outside parties ("experts") teach a course in an educational programme, there are also some almost equally obvious disadvantages. The main problem is an oftentimes weak understanding of, and a tenuous link to core issues in the programme and to the orientation to, and interests of the students in question. If sufficient in-house competence and interest in relevant topics can be located (which is perhaps most often *not* the case), it is our belief that it is preferable that such a course should be developed and taught in-house. This becomes all the more important when many media technology and computer science engineering students suffer from the preconceived opinion that sustainability is at best a peripheral matter, and at worst irrelevant to their education. A key challenge for any educator will thus be to shape any such course in ways that make the course contents relevant and possible for the students to relate to. This has indeed been - and continues to be - one of our main challenges in developing and teaching the course in question.

A second reflection is that ICT4S is a fairly new field of research, and that even we as researchers are still struggling with suggesting *numerous* examples of what ICT can *practically, for our students*, be used for in the area of sustainability. This means that the students might not get the ready answers they are seeking, and that they are instead given an open-ended palette of ideas and research results that they themselves have to form their own path through and work on applying to their future professions.

Thirdly, we could hone the students in only considering ICT and sustainability rather than sustainability in a larger scope, but there are some disadvantages with this. This is a tension we have been discussing in our previous paper [16], and we argue here that we need these future engineers - who will be obliged to take active part in transforming our society to become more sustainable - to at least know about "the bigger picture". Hence we cannot exclusively emphasize (only) ICT and sustainability but also need to impart an overarching understanding of sustainability when it isn't necessarily connected to information and communication technologies. Moreover, there are also obvious limitations to trying to educate fully developed sustainability-aware practitioners in one single course. The results presented in this paper do indicate that sustainability needs to be integrated in the entire educational programme to a much higher extent since one single course on sustainability, in a five-year long education, is just not enough. We have this far not had the opportunity to do this integration, but it will be something we will strive for henceforth.

Fourthly, we suggest that there are a number of "tensions" [16] that any educator needs to think about when planning and giving similar courses and that these include 1) the tension between sustainability in general and ICT4S in particular, 2) the tension between personal habits and choices (at the present) and professional (future) roles and actions[6], 3) the tension between delivering facts and working with/on values in a university-level course and 4) the tension between normative dimensions (what things should really be like) and practical realities (what we can do at present).

IX. Conclusions

The aim of this paper has been to reflect on how ICT4S can be integrated into higher education. We argue that the ICT4S community needs to a find and shape a variety of ICT4S topics that are adapted to varying student bodies ("target audiences") in a user-centred manner [25-27]. ICT4S can for all practical purposes *not* be squeezed into a single course, but should instead optimally influence and be integrated into a variety of courses and modules [12] - if the end goal is to get the students engaged and acting (and by extension to change society in a more sustainable direction!).

A resource for helping educators move in that direction is the "Computing Education for Sustainability Framework"

---

[6] Changes in diets or travel/vacation habits pertain to personal habits and choices, while the professional role could involve for example to adhere to "sustainable web design" practices
(http://alistapart.com/article/sustainable-web-design)

presented by Mann et al. [12]. The framework helps teachers assess resources that are suitable for their specific situation by posing a set of questions. However, this is only one way of addressing the issue and further research is needed in the ICT4S education area. The integration of sustainability topics into higher education requires the support at different level, and perhaps also in policies for strengthening such efforts. One example of such a policy is discussed in [32] and the policy in question was later approved by the ACM SIGCSE in 2012. However, this is perhaps not enough in order to truly educate students to become the ICT engineers our future needs. To reach such goals, there is a need to transform education, with sustainability and a sustainable society as the main objective rather than a patch-on [14]. Regardless of the path one chooses, our recommendation is for the ICT4S community to not only "develop research and education for ICT4S" [18], but rather also conduct research *on* education for ICT4S.

Acknowledgment

References

[1] T. Stocker, D. Qin, G. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. Midgley, "Climate Change 2013: The Physical Science Basis. *Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Summary for Policymakers". 2013.

[2] B. McKibben, "Eaarth: Making a life on a tough new planet". 2011: Random House LLC.

[3] W. Steffen, J. Grinevald, P. Crutzen and J. McNeill, "The Anthropocene: conceptual and historical perspectives". Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 2011. Vol: 369 No: 1938: p. 842-867.

[4] K. Aleklett, "Peeking at peak oil". 2012: Springer.

[5] M. T. Klare, "The race for what's left: the global scramble for the world's last resources". 2012: Macmillan.

[6] J. Rockström, W. Steffen, K. Noone, Å. Persson, F. S. Chapin, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke and H. J. Schellnhuber, "A safe operating space for humanity". Nature, 2009. Vol: 461 No: 7263: p. 472-475.

[7] A. M. Townsend, "Smart cities: big data, civic hackers, and the quest for a new utopia". 2013, New York: W. W. Norton & Company, Inc.

[8] P. Wäger and R. Widmer, "Keynote: Scarce Metals as Raw Materials for ICTs: Do We Care Enough?". 2013: ICT4S 2013.

[9] S. Umair, A. Björklund and E. Ekener Petersen "Social Life Cycle Inventory and Impact Assessment of Informal recycling of Electronic ICT Waste in Pakistan". In Proc. ICT4S 2013, 2013, 52-58

[10] GeSI, "GeSI SMARTer 2020: The Role of ICT in Driving a Sustainable Future". 2012.

[11] L. Hilty, W. Lohmann and E. Huang, "Sustainability and ICT—an overview of the field". POLITEIA, 2011. Vol: 27 No: 104: p. 13-28.

[12] S. Mann, L. Muller, J. Davis, C. Roda and A. Young, "Computing and sustainability: evaluating resources for educators". ACM SIGCSE Bulletin, 2009. Vol: 41 No: 4: p. 144-155.

[13] Y. Cai "Integrating sustainability into undergraduate computing education". In Proc. SIGCSE'10, ACM, 2010, 524-528

[14] S. Sterling, "Higher education, sustainability, and the role of systemic learning", in Higher education and the challenge of sustainability: Problematics, Promise and Practice, P. B. Corcoran and A. E. J. Wals, Editors. 2004, Springer: Netherlands. p. 49-70.

[15] K. Sammalisto and T. Lindhqvist, "Integration of sustainability in higher education: a study with international perspectives". Innovative Higher Education, 2008. Vol: 32 No: 4: p. 221-233.

[16] D. Pargman and E. Eriksson ""It's not fair!"-making students engage in sustainability". In Proc. EESD'13, 2013,

[17] T. Cheshire "Europe's hottest startup capitals: Stockholm". WIRED, 2011. [accessed: URL: http://www.wired.co.uk/magazine/archive/2011/09/european-startups/stockholm/viewall.

[18] ICT4S "Conference Recommendations: How to Improve the Contribution of ICT to Sustainability". ICT4S'13, 2014. [accessed: 2014-02-25].

[19] R. Heinberg and D. Lerch, "The post carbon reader: managing the 21st century's sustainability crises". 2010: Watershed Media.

[20] J. Robinson, "Squaring the circle? Some thoughts on the idea of sustainable development". Ecological economics, 2004. Vol: 48 No: 4: p. 369-384.

[21] G. H. Brundtland, "Our common future: The world commission on environment and development". 1987, Oxford: Oxford University Press.

[22] D. Griggs, M. Stafford-Smith, O. Gaffney, J. Rockström, M. C. Öhman, P. Shyamsundar, W. Steffen, G. Glaser, N. Kanie and I. Noble, "Policy: Sustainable development goals for people and planet". Nature, 2013. Vol: 495 No: 7441: p. 305-307.

[23] J. A. Tainter, "Energy, complexity, and sustainability: A historical perspective". Environmental Innovation and Societal Transitions, 2011. Vol: 1 No: 1: p. 89-95.

[24] R. Heinberg, "Peak everything - Waking up to the century of declines". 2007, Gabriola Island, BC: New Society Publishers.

[25] J. Gulliksen, B. Göransson, I. Boivie, S. Blomkvist, J. Persson and Å. Cajander, "Key principles for user-centred systems design". Behaviour & Information Technology, 2003. Vol: 22 No: 6: p. 397-409.

[26] J. Karat, "Evolving the scope of user-centered design". Communications of the ACM, 1997. Vol: 40 No: 7: p. 33-38.

[27] J. Gould and C. Lewis, "Designing for usability: key principles and what designers think". Communications of the ACM, 1985. Vol: 28 No: 3: p. 300-311.

[28] J. L. Zapico, M. Guath and M. Turpeinen, "Kilograms or cups of tea: Comparing footprints for better CO_2 understanding". PsychNology Journal, 2011. Vol: 9 No: 1.

[29] E. A. Avallone, T. Baumeister III and A. M. Sadegh, "Marks' Standard Handbook for Mechanical Engineers 11th Edition". 2007, New York: Mc-Graw Hill.

[30] K. F. Mulder, J. Segalas and D. Ferrer-Balas, "How to educate engineers for/in sustainable development: Ten years of discussion, remaining challenges". International Journal of Sustainability in Higher Education, 2012. Vol: 13 No: 3: p. 211-218.

[31] J. Dahlin, P. Larsson and C. Erlich "The use of board games in the engineering education for the purpose of stimulating peer participation in lecture theatre discussions". In Proc. EESD'13, 2013, 92-100

[32] S. Mann, L. Smith and L. Muller, "Computing education for sustainability". ACM SIGCSE Bulletin, 2008. Vol: 40 No: 4: p. 183-193.