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Raising Awareness for Potential Sustainability Effects in Uganda: A Survey-based Empirical Study

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***Abstract*—In July 2019, we ran the 3rd International BRIGHT summer school for Software Engineering and Information Systems at the Makerere University in Kampala, Uganda. The participants developed a group project over the course of the week, which included the application of the Sustainability Awareness Framework. The framework promotes discussion on the impact of software systems on sustainability based on a set of questions.**

In this paper, we present the educational evaluation of the Sustainability Awareness Framework in a country in Sub-Saharan Africa. The results indicate that the framework can provide supportive guidance of the societal and environmental challenges in the given context.

Keywords: sustainability, requirements engineering, software-intensive systems, socio-technical systems, ICTD

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1. Introduction & Background

The BRIGHT Summer School [9], this time hosted by Makarere University in Kampala, was held in Uganda for the third time in the summer of 2019.

As a change to previous editions, which focused more exclusively on project development, this year the focus was on contributing to the development of research project ideas and grant proposals for local sustainability challenges.

Sustainability, which is defined as the "ability to endure" [1] [4], has become one of the greatest concerns of our society. The nature and pervasiveness of software systems means that they can have a considerable impact on our sustainable development [5], for better or worse. Hence, the summer school included a couple of sessions on "Software Engineering for Sustainability".These sessions aimed at raising awareness for this potential impact and offering tools to help software engineers step up to their role of designing the future with consciousness.

The foundation for the work presented in the paper at hand has been established by the Karlskrona Alliance for Sustainability Design [3]. The group advocates for the importance of Sustainability Design in software engineering [2]. Among other techniques, it developed the **Sustainability Awareness Framework (SusAF)**, which intends to raise awareness about the potential impact software systems can have on sustainability [6]. The framework is composed of a set of guiding questions for each of the five sustainability dimensions [7], [10], an adapted radar chart that we call the Sustainability Awareness Diagram (SuSAD) to capture potential effects over dimensions an order of effects [8], and a set of instructions for using the questions and drawing the diagram.

In the following, we present how the summer school was organized, the projects the students worked on, and the results of the survey evaluation we performed at the end of the week with regards to SuSAF.

2. Background: SusAF

The Sustainability Awareness Framework (SusAF) [6] is an approach developed by Duboc et al. over the past years that was conceptualized using a design science approach and iterated in three design cycles. It serves to raise the awareness of potential sustainability impacts in the five dimensions of sustainability (social, individual, environmental, technical, and economic) [10] along three orders of effect [8]. The idea was informally introduced in [2] and then developed into a framework applicable across a wider range of scenarios, including discussions in development

teams, interviews with stakeholders, and dedicated stakeholder workshops.

The framework uses a set of questions per dimension, structured in five topic areas, namely:

- Social: (1) Sense of Community; (2) Trust; (3) Inclusiveness and Diversity; (4) Equality; (5) Participation and Communication;
- Individual: (1) Health; (2) Lifelong learning; (3) Privacy; (4) Safety; (5) Agency;
- Environmental: (1) Material and Resources; (2) Soil, Atmospheric and Water Pollution; (3) Energy; (4) Biodiversity and Land Use; (5) Logistics and Transportation;
- Economic: (1) Value; (2) Customer Relationship Management (CRM); (3) Supply chain; (4) Governance and Processes; (5) Innovation and R&D;
- Technical: (1) Maintainability; (2) Usability; (3) Extensibility and Adaptability; (4) Security; (5) Scalability

The questions allow the user to explore the key topic areas of each sustainability dimension, even if they are not an expert in the area. That way, the framework does not proclaim to be an analysis tool but a way to increase the awareness for certain effects the system may have in its operational as well as business environment.

The results of the discussions in the five dimensions get summarized in a Sustainability Awareness Diagram in form of a radar chart. The diagram serves as decision making support on which actions to take and which sustainability experts to further involve to perform an in-depth analysis if necessary.

The approach has been evaluated in seven universities and six companies. Part of the educational evaluation is described in [6]. The following research questions were addressed both in [6] and, for evaluation in a different setting, in the paper at hand:

RQ1: Does the framework encourage insightful discussions about the potential effects of software systems on sustainability?

RQ2: Does the framework help to identify the potential chains-of-effects of software systems on sustainability?

RQ3: How practical is the proposed approach?

3. Organization of the Summer School

We had thirty participants, mainly from Uganda, plus one from Rwanda and one from Turkey. The levels were mixed - there were a few Bachelor students, a few Master students, about a dozen PhD students, a few lecturers, and a few staff members.

The summer school was organized as follows: On the first day, Andy Dearden moderated a brainstorming group exercise to come up with a number of sustainability challenges and corresponding application domains. Subsequently, the students self-selected teams around those challenges, identified a more specific challenge, and developed a rich picture for it. The rich pictures included an elicitation of important stakeholders and their main concerns.

The second day targeted the discussion and analysis work leading to the Sustainability Awareness Diagrams, according to Duboc et al. [6], led by Birgit Penzenstadler. The evaluation of this part is the main reported result in the paper at hand.

The third day, led by Eric Umuhoza was used for business process modeling of the system and its operational environment. On day four, Dorothy Okello instructed students on how to write good grant proposals, specifically targeting funding agencies in Africa. The students presented their results on day five, including the research questions they derived for future grant proposals.

4. Team Project Results

We had six teams who developed their research challenges and system ideas over the course of the week. Their project topics were as follows:

- Aviation Operations Ecosystem: This team investigated the sustainability of daily operations at an airport, with focus on direct interaction with the travelers.
- Malaria Prevention System: This team engaged with opportunities to improve malaria prevention in rural Uganda with mobile health workers.
- Healthcare in Rural Areas: This team looked into extending the services that mobile health providers can bring to remote villages.
- Agriculture Extension Services Against Climate Change: This team worked on potential extension services that could support farmers in dealing with the changes climate change is bringing.
- Food Safety Information System: This team developed a set of interventions to improve food safety from the harvest location to delivery to the end consumer.
- University Career Support Services: This team provided an analysis of opportunities to improve the extension services to students in support of job search and career start before, at, and after graduation time.

Based on the elicitation day, the teams developed a stakeholder analysis, a sustainability awareness diagram, a business process model, and a research agenda for a more involved investigation of the project.

5. SuSAF Instructions and Guidance

For the Sustainability Design day, students started out with a set of guiding questions per dimension which they discussed in their teams. The complete set of questions and worksheets is published by Duboc et al. [6].

In contrast to previous educational evaluations, in the summer school students did not have the time to perform interviews. Instead, they asked one of the facilitators in case

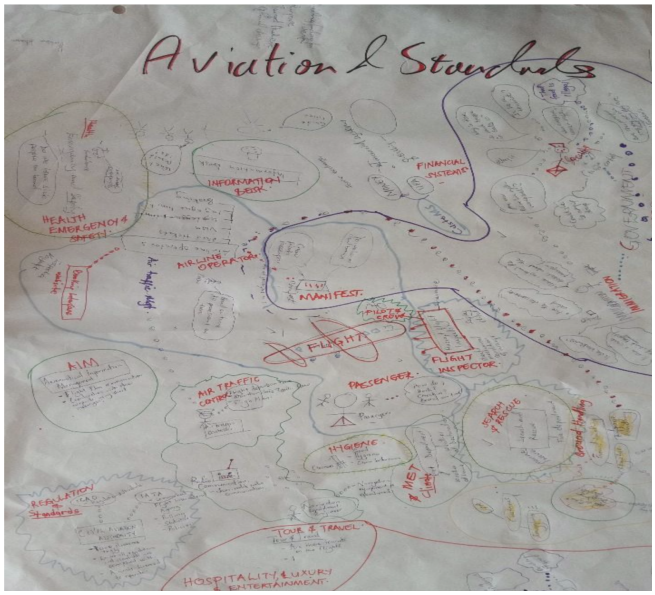

Figure 1. Sample: Rich Picture of the Aviation Operations Ecosystem Team.

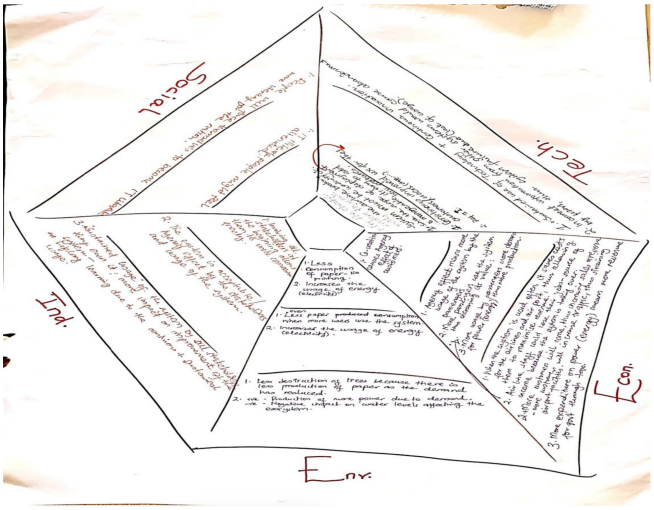

Figure 2. Sample: Sustainability Analysis Diagram of the Aviation Operations Ecosystem Team.

How long did it take to conduct the discussion of all dimensions?
Have you understood the questions?
Which questions were not easy to understand? (Keywords?) And why?
Did you have difficulties in answering the questions? Why?
Did you get insightful answers using the questions in this domain? Why?
Did you ask about the “extreme scenario” for key topics? Why, or why not?
Have you been able to think of chains of effects (e.g. more trust leads to more participation, which again leads to increased health)?
For how many key topics could you think of chains of effects?
Did anything come up that you didn’t expect? If yes, what?

TABLE 1. SURVEY RESULTS ON THE GUIDING QUESTIONS

they got stuck with a question or were lacking background knowledge. Over the course of a few hours, they worked their way through the dimensions, engaged in vivid discussions with each other, and drafted their initial versions of the Sustainability Awareness Diagrams.

Figure 1 shows the Rich Picture of the Aviation Team with all main stakeholders and concerns as well as involved technical and social systems. While the picture is hard to read, it is only intended to give an impression of the level of involvement and discussion that each of the teams experienced during their elicitation sessions.

Figure 2 presents their Sustainability Awareness Diagram with a summary of potential sustainability effects across all five dimensions (chart sectors) and the three orders of impact (radial axes).

6. Evaluation Results & Feedback

We evaluated the summer school in a combined survey on 1) how participants perceived the entire summer school this year and 2) specifically the usage of SuSAF and 3) if they had participated last year, what benefits, if any, had been perceived over the last 12 months.

We received 24 filled out replies. In the following, we only report on the SuSAF part of the evaluation. The questions on the Guiding Questions are listed in Tab. 1, and on the Sustainability Awareness Diagram in Tab. 2.

6.1. Results for Guiding Questions

The individual results per question on the Guiding Questions (Tab. 1) indicate that the participants found the questions helpful as they got insightful answers from them, they helped to think of chains of effect, and they brought up unexpected items in the discussion. In detail, the results were as follows:

How long did it take to conduct the discussion of all dimensions? Participants took an average of 2.6 hours discussing the questions. Seven participants declared having spent around 1 hour, seven said they spent between 3-4 hours and 2 around 5 hours. Three people declared having spent 0.5, 2 and 8 hours, respectively.

Have you understood the questions? Rate from 1 (not at all) to 5 (completely): Eighteen (78.2%) participants rated the questions as easy to understand, giving a rate of 4-5 out of 5. Three (13%) had some difficulty (rate 3 out of 5) and

Have the questions helped to identify possible effects? If yes, how much? If no, why?
How easy was it to identify possible effects for each dimension?
What, in addition to the questions, would have helped you to identify possible effects?
Did the questions help to fill out the Sustainability Analysis Diagram (SusAD)?
Was the resulting SusAD readable? Why (not)?
Was the resulting SusAD useful? Why (not)?
Is there anything else you would like to comment on?

TABLE 2. SURVEY RESULTS ON THE SUSTAINABILITY AWARENESS DIAGRAM

two (8.6%) found them difficult to understand.

Which questions were not easy to understand? (Keywords?) And why? Most students referred to dimensions (all have been mentioned), rather than questions. No question/dimension stood out. The environmental and technical dimensions were mentioned more frequently (three times each). Reasons varied from uncertainty of the future, lack of knowledge about system, lack of understanding of the dimension itself.

Did you have difficulties in answering the questions? Rate between 1 (not at all) and 5 (a lot): On average, participants had some difficulty in answering the questions (rate 3.08 out of 5). Six participants (25%) felt very little difficulty (rated 1-2), nine (37.5%) had some difficulty (rated 3), and eight (37.5%) has some difficulty (rated 4-5). *Why?* Several reasons where given for their difficulty. The most cited one was the difficulty to relate the idea/system with sustainability (3 citations). Other reasons where unfamiliarity to the topic or context, difficulty in understanding the questions, the need for critical thinking and the little time given to the exercise.

Did you get insightful answers using the questions in this particular domain? Rate between 1 (not at all) and 5 (a lot): Despite their reported difficulty in answering the questions, most participants felt that they got insightful answers, with 29% giving a rate of 3 and 62.5% rating between 4 and 5. *Why?* The most cited reason was that the questions promoted discussion within the group (four times). Others were that the questions were relevant to their project/domain and widened their thinking (e.g. "they got me thinking deeper").

Did you ask about the "extreme scenario" for different key topics? Rate between 1 (never) and 5 (always): In general, participants remembered to consider the extreme scenario, which nearly 74% rating between 3 to 5 out of five.

Why, or why not? The participants who used the extreme scenario, normally justified that it allowed them to further explore the topics. For example, participants said that the extreme scenario does "show long term safety and environment concerns - something good to think about in terms of sustainability" and that it "highlighted the systemic effects for each issue". Two that did not use the scenario said they did not understand the framework well and were struggling to understand the principles, respectively.

Have you been able to think of chains of effects (e.g. more trust leads to more participation, which again leads to increased health)? Rate between 1 (not at all) and 5 (always): With an average of 4 out of 5, most participants declared that they could normally think of chains of effects, with 66% rating 4 to 5 and 19% rating 3, all out of five. Only one student could not think of any chain of effect at all.

For how many key topics could you think of chains of effects? Most participants (71.4%) were able to think of chains of effects for more than 4 topics. The remaining identified chains for 2 to 3 topics.

Did anything come up that you didn't expect? Most participants (66.7%) felt that the questions brought up unexpected considerations.

If yes, what? Few gave reasons. Two were surprised by the potential environmental effects, while other two didn't expect the rebound effects. A couple were just happy with the experience. Interestingly, one of the five participants who felt that the questions did not bring anything unexpected, said that "Being a social scientist I was able to integrate the course with my knowledge so its really been helpful".

In summary, the participants found the questions useful for getting insights on the key topics as well as chains of effects and discovering new discussion items.

6.2. Results for Sustainability Awareness Diagram

The individual results per question on the Sustainability Awareness Diagram (Tab. 2) indicate that it was possible to identify effects using the questions, and that the resulting diagram was readable and useful. In detail, the responses were as follows:

Have the questions helped to identify possible effects? The vast majority (95,6%) felt the questions helped them to identify possible effects. Only one participant didn't feel the questions were helpful to that end.

If yes, how much did the questions help to identify possible effects? Rate between 1 (a little bit) and 5 (a lot): Most (58.8%) gave the questions a rate between 4 and 5, out of 5. 23.5% felt the questions had been reasonably helpful (rate of 3 out of 5) and only one felt it helped a little (rate 1 out of 5).

If no, why? The only participant who felt the questions were unhelpful, said he or she probably needed more time.

How easy was it to identify possible effects for each dimension? Per dimension, 1 (very easy) to 5 (very difficult).

Social: Most participants (75%) felt that it was easy to identify potential effects on the social dimension (rate of 1 and 2 out of 5). The remaining ones (25%) felt it was not particularly easy or difficult (rate of 3 out of 5).

Individual: The individual dimension had similar results, with 75% of the participants finding it quite easy to identify potential effects (rate of 1 and 2 out of 5), 20% stating that it was neither easy or difficult (rate of 3 out of 5) and only one reporting some difficulty (rate of 4 out of 5).

Economic: Answers regarding the economic dimension were more evenly distributed. Around 43% of the respondents had no difficulties (rate of 1 and 2 out of 5), 39.1% felt indifferent (rate of 3 out of 5) and 17.4% reported difficulty (rate of 4 to 5 out of 5).

Environmental: The results for the environmental dimension were quite similar. 37% of the participants identified potential effects with ease (rate of 1 and 2 out of 5), 41% felt it was neither particularly difficult or easy (rate of 3 out of 5), and the remaining 20.8% had difficulties (rate of 4 to 5 out of 5).

Technical: Finally, the for the technical dimension, most respondents (54.2%) found potential effects easily (rate of 1 and 2 out of 5), 20.8% felt quite indifferent (rate of 3 out of 5), and 25% experienced difficulties (rate of 4 out of 5). From these results, we can see that the social and individual

dimensions were the easiest ones to discuss, while the other ones were slightly more difficult.

What, in addition to the questions, would have helped you to identify possible effects? Participants have identified several other things that could have helped then further, like more discussion (cited by 3), an example (cited by 2), more input from the domain (cited by 2), more time and prior knowledge of the solution (cited by 1 each). Sample quotes were "Discussions and interactions with members of different groups", "More study - user centered design methods like observation, interviews, literature review", "interaction with key stakeholder".

Did the questions help to fill out the Sustainability Analysis Diagram (SusAD)? Rate between 1 (very helpful) and 5 (not helpful at all). The majority of the participants (78.9%) felt that the questions were helpful to fill out the SusAD (rates of 1 and 2 out of 5). Around 15% were indifferent (rate of 3 out of 5) and 10% disagreed (rates of 4 and 5 out of 5).

Was the resulting SusAD readable? Rate between 1 (perfectly) and 5 (not at all). Also, most respondents (85.7%) felt that the resulting SusAD was easy to read (rates of 1 and 2 out of 5), one participant was indifferent and 2 disagreed (rates of 4 out of 5).
Why? The ones who disagreed justified that "because the questions clearly spelled out how to fill out the chart". Others felt that the chart were easily readable because "because the questions clearly spelled out how to fill out the chart" and "we made sure to write only a few items so that they fit well".

Was the resulting SusAD useful? Rate between 1 (perfectly) and 5 (not at all). When asked whether the resulting SusAD was useful, 90% of the responded agreed with this notion (rates of 1 and 2 out of 5). Just one was indifferent (rate of 3 out of 5) and another disagreed (rates of 4 out of 5).
Why? The reasons why participants were happy with the results were: "It enabled us to analyse our project from a very broad perspective", "Helped us understand how the project can grow", "helps to look at all areas a funder would like to ask", "can be applied in every day life", "Gives chance to think of how best to design system in a more reliable way", "it got us thinking and allowed us to think beyond the box". The responded who did not find the SusAD useful did not give an explanation.

Is there anything else you would like to comment on? Finally, when asked whether they would like to comment on something else, most students just talked about the Summer School in general or thanked for the interesting lecture. The one who specifically referred to the SusAF said "It was a new way of understanding sustainability, helped me improve knowledge in this area. I can relate my research very well to sustainability with the diagram." Another suggested "to give more resources about model / teamwork".

In summary, the participants found that effects could be identified well using the questions, and that the resulting Sustainability Awareness Diagram was readable and useful.

7. Discussion

While the research questions were answered confirmatory in both cases, there are still a number of issues up for discussion, in terms of reflection on the evaluation, threats to validity, and comparison to previous evaluations.

7.1. Reflections on the Evaluation

Education stages. The participants of the summer school were at very different stages of their education, starting from Bachelor's, including Master's students, PhD students as well as lecturers and professors. This diversity might explain some outliers in rating for the the *easy to understand* question.

Unfamiliarity with Concept of Sustainability. Some students had difficulty to relate an idea they came up with for a project with the concept of sustainability. We are under the impression that this may be the case more commonly than expected - we have a sustainability label here at GU that we can put on courses which is very underused, because many teacher think that their courses do not address "that form of" sustainability.

Insightful Answers. On the question about insightful answers, we found the participants' responses interesting, because they could be given completely independent of the sustainability aspect (or targeted solution). This could be considered a (useful) side effect, since sustainability is so woven into all aspects of a domain that a tool to systematically think about sustainability forces you to further explore the domain.

Extreme Scenario Usage. With regard to the question on the usage of the extreme scenario, there is a very large overlap of the 74% who used the extreme scenarios with the 78% who understood the questions. That means we basically have a close to 100% percent use of this part of the tool, which is great in terms of transfer from one stage of the method to adaptation of the next, which we consider a good outcome and a promising indicator in terms of application in a real-world setting.

Ease & Difficulty of Specific Dimensions. Considering the perceived ease or difficulty of specific dimensions, it is not a surprise that the technical dimension was not the one to be perceived most difficult since we had a rather technically-educated set of participants. However, it is a surprise that even for these participants the technical dimension is harder than, e.g. the social or individual dimension. The difficulty with the environmental dimension might play into the same issue that we had about relating the general project idea to sustainability. The environmental dimension seemed to be the most prominent when discussing about sustainability — this leads to the question of whether we need to better communicate a) aspects of the dimension itself or b) the other dimensions?

Additional Help Suggestions. In terms of what would have helped in addition, the participants had good answers and showed an understanding of effective educational means. The course was only a simulation for a longer course,

project and one would of course expect to have more time and study the topics on a deeper level to go into this kind of analysis. However, considering the available time frame, the students made the most of the instructors' support to get a deeper insight into how sustainability can be perceived and understood in different dimensions and what the different impacts over time might be.

7.2. Threats to Validity

Threats to validity hamper the ability to draw conclusions from the evidence [11].

For the feasibility study, which uses the same instrument as [6], one of the main risks is the reactive bias, as the students might answer the questionnaire positively to meet the expectations of their teachers (i.e. "halo effect"). In addition, there are several confounding factors which may affect the outcome that were not taken into account, such as differences in knowledge regarding sustainability issues of the students. However, we endeavor to ensure a similar perspective on sustainability and knowledge of the questions and the SusAF method by delivering the introductory session and instructions. Another main risk is the possible bias caused by result interpretation. We applied researcher triangulation and mixed qualitative and quantitative methods to minimize this risk.

Last but not least, we do not attempt to generalize the findings from this application case. Instead, we demonstrate the feasibility of using the SusAF for relating the requirements engineering process to topic of sustainability in a specific context. It is an additional data point for Duboc et al. [6].

7.3. Comparison to Previous Evaluations

We have previously used the same instrument to evaluate SusAF in academic contexts at other universities [6], namely the Lappeenranta University of Technology in Finland and the California State University Long Beach in California, USA. Our findings confirm the ones in the previous study, this time for the context of an educational setting in a Sub-Saharan country in Africa — a setting where the societal and environmental challenges significantly differ from the ones experienced in Finland and the USA. Also in the context at hand, the framework was found to encourage insightful discussions (RQ1), to help identify chains of effects (RQ2), and to be practical (RQ3).

Further evaluation has been performed with first industry partners, indicating similar tendencies.

8. Conclusion

The overall evaluation of the summer school was decidedly positive and the authors are working on securing follow-up funding for future iterations of the BRIGHT Summer School series.

The results of the SuSAF evaluation indicate that the SuSAF can be applicable and useful within an educational setting in the context of sustainability challenges in a Sub-Saharan country.

In conclusion, we confirm the evidence of Duboc et al. [6] that the Sustainability Awareness Framework provides a simple and accessible framework to elicit awareness of the impacts that software-intensive systems could have.

For future work, several research proposals are currently under development based on the results of the summer school, and SusAF is now being evaluated in industrial contexts.

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