"Wow, that's a LOT!" Increasing Engagement and Understanding in Sustainability Using Tangible Learning Methods

Björn Hedin, *KTH Department of Learning*, Anders Blomqvist, *Vetenskapens hus*, Arjun Rajendran Menon, *KTH Division of Media Technology and Interaction Design*

***Abstract*—Facilitating active engagement of students, prospective students, and teachers in addressing societal challenges is of paramount importance for society. One such challenge is sustainable development, an issue that many acknowledge at a foundational level but find challenging to personally connect with. In this paper, we share our initial findings on the use of "physicalization" of environmental data as an educational tool. We have created tangible objects that represent environmental data, providing prospective university students, current students, and teachers with a hands-on, tangible learning experience, ultimately aiming to generate interest and active engagement in these subjects. We hope that this, in turn, increases the likelihood that students will continue to pursue these topics throughout their educational journeys and future careers.**

***Index Terms*—Physicalization of data, Student recruitment, Student engagement, Education for sustainable development**

I. Introduction

Higher education in the field of technology is increasingly committed to addressing critical societal and global issues, such as the establishment of a sustainable society, rather than solely imparting technical knowledge. Simultaneously, technical universities face challenges in recruiting the most accomplished students. One way of tackling both these issues is to develop strategies and methods for making sustainable development and questions about justice feel more tangible and emotionally engaging, and clarifying the connection to how technology and technical development can be a tool for this. If such methods then can be deployed on several levels (upper secondary school students choosing their future educational paths, technology students, and teachers of technology students), progress towards these goals will be made.

This paper outlines our approach to utilizing 'physicalization' of sustainability data to create compelling and memorable experiences related to sustainable development. As defined by Jansen et al [1], a data physicalization is a tangible object whose shape or material properties convey data. We have applied physicalization to sustainability data related to energy and greenhouse gases, topics that difficult to relate to [2-4], across three distinct pedagogical settings. The first is designed as a 60-minute learning module for secondary school students visiting a science center. The second is designed for a science fair for upper secondary school students, with brief interactions lasting around 5 minutes. The third is designed for a higher education pedagogical course focused on integrating sustainable development into teaching, intended for teachers at technical universities, featuring a 30-minute interaction. In this paper, we will briefly describe the setup for the first two.

II. The pedagogical setups

The three different pedagogical setups had different target groups, different aims, and different timeframes. However, all setups have a common aim, which is to cause a memorable surprise effect when large differences are made concrete and explicit using physicalization of the data.

A. 60-minute module at a science center

This module was developed for the Science Education Center "Vetenskapens hus". A driving idea of Science Education Centers is to serve as catalysts for sparking a passion for science among young learners, providing them with the opportunity to engage in hands-on laboratory activities within an inspiring learning environment.

This specific module targeted second- and third-year secondary school students studying natural science and technology, making them prospective candidates for enrollment in higher education programs within STEM fields. Two classes of approximately 30 students each were divided into a total of four groups of 14-16 students. Each of these groups then participated in the activity separately. Upon entering the classroom, the subgroups were further divided into four groups of 3-4 students each and seated at separate tables. The following steps were then carried out:

1. The group received a brief introduction from a teacher about the main theme of the day (greenhouse gases, sustainable travel, and sustainable food, with only the food part described here). They were shown an image outlining the main components of the food system that contribute to greenhouse gas emissions from food (agriculture, processing, land-use change, transport, packaging). This served as an onboarding activity, setting the stage, and introducing some fundamental concepts.

Björn Hedin (e-mail bjornh@kth.se) is an associate professor at KTH Royal Institute of Technology, department of learning.

Anders Blomqvist (e-mail anders.blomqvist@vetenskapenshus.se) is pedagogical developer at the science center Vetenskapens hus, associated with KTH Royal Institute of Technology and Stockholm university.

Arjun Rajendran Menon (e-mail armenon@kth.se) is a doctoral student in media technology and interaction design at KTH Royal Institute of Technology.

2. The students were presented with an image of five food products, each weighing 500 grams (minced meat, salmon, tomatoes, rice, and potatoes).

3. The students were tasked with individually ranking the food products based on their greenhouse gas emissions, entering their rankings using their phones through a digital tool. This was done so that every student individually had to take a stance, which is important for a learning effect to ensue from a surprise [5].

4. Each group/table was then instructed to discuss their rankings and arrive at a group consensus. This ranking was physically represented by ordering disks with pictures of the food products (see the yellow disks on the left in Figure 1). These discussions were important for the peer learning, allowing students to engage in meaningful conversations with their peers. Two red herrings were included in the food products chosen, one requiring long transports (by boat), which contrary to popular belief is not a big contributor to greenhouse gas emissions, and one organic product which has many environmental benefits, but where lower greenhouse gas emissions is not one such factor.

5. Once the group ranking was completed, a table with physical representations of the food products in their actual size was brought out (see Figure 1). Each group was then required to place the artifact next to the disk with the corresponding product's picture. This moment served as a highlight of the entire module, allowing them to physically feel the significant differences between the various products. Almost all participants were surprised by the differences, especially for the heavy products, which made the experience memorable and opened an opportunity for learning [6-8].

6. Finally, a teacher conducted a debriefing of each product, explaining the reasons behind the high or low emissions associated with each one.

B. 5 minute module at a science fair

A similar setup was used at a science fair with the same type of students visiting, but where they participated on a voluntary basis, with several stations competing for the students' interest. Since we could not aim to keep the interest of students for more than a couple of minutes, this setup contained only steps 4-6, and the debriefing was quicker. We also introduced another module about fairness in the distribution of greenhouse gas emissions among different countries and different income groups. Steps 4-6 were used, where bags with weights were used in step four to represent personal greenhouse gas emissions per day from different groups in the world (Figure 1, right). However, a step 4.5 was added where the students should quantify the differences after doing the ranking. This was done by adding poker chips representing emissions to plastic tubes, as shown in Figure 1 (middle).

III. Results, Discussion, and Conclusion

The evaluation will be presented in other papers, but briefly showed that for the first activity, the students liked the activity, and that what they learned was retained at least one month after the event. For the second activity the students estimated the differences relatively correctly, but even so, they were really surprised by the weight of the emissions of the worst countries and richest people in the world, and that most were likely going to talk about the results to friends and family afterward.

To conclude, these early tests of tangible learning using data physicalization have been very promising and the activities have made a deep impression upon the participants. Possible uses of these methods for different target groups will be the focus of our future efforts.

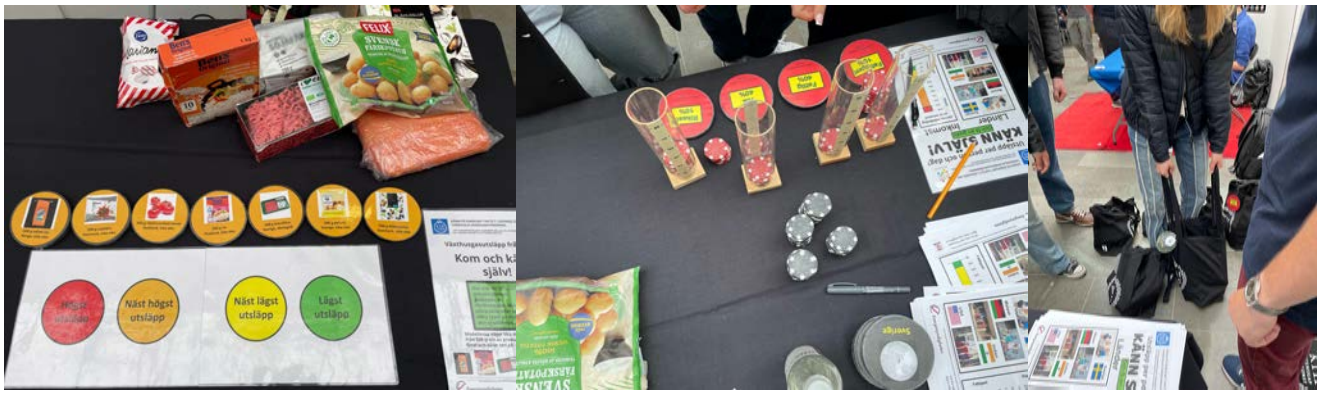

Figure 1. A setup of the food activity (left) and carbon justice activity (middle and right)

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