



# SDGs Like You Have Never Seen Before!: Co-designing Data Visualization Tools with and for University Students

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## ABSTRACT

Sustainability is currently a hot topic also inside universities. Every year, several universities publish an open report based on their efforts to achieve the 17 Sustainable Development Goals (SDGs). However, the university community is often unaware of these reports and does not know how an individual can contribute to sustainability inside and outside the university premises. To partly tackle that, we exploited a three-step process composed of interviews, data analysis, and co-design to understand which data are relevant in this context and what elements an interactive data visualization system should have to raise awareness of the actions performed by the university, and of what can be done by the university community to improve the overall sustainability of the campuses. In this paper, we present our experience in co-designing solutions with students of the University of Bologna. We finally extract some guidelines that can be exploited in a similar context to make university sustainability reporting an action toward a more sustainable future.

## CCS CONCEPTS

• **Human-centered computing** → **HCI design and evaluation methods; Interactive systems and tools.**

## KEYWORDS

sustainability, awareness, co-design, university

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## 1 INTRODUCTION

The 2030 Agenda has significantly increased the obligations of universities towards their students and the community, as stated by the United Nations in 2015 [2]. This shift has positioned higher education as a critical player in the transition towards sustainable development [12, 26]. In light of these new responsibilities, universities now face a growing demand for heightened accountability, as emphasized [22]. As public sector institutions, many universities are also experiencing mounting institutional pressures and stakeholder expectations for increased commitment in disclosing sustainability-related information in order to act responsibly [11, 22]. Furthermore, given the pivotal role of universities in educating future generations and shaping a sustainable society, it has become crucial to assess the impact of higher education institutions in terms of sustainable development and sustainability effects. In this regard, scholars have highlighted the importance of measuring these impacts to ensure that universities are actively contributing to a more sustainable future [14, 21].

Unfortunately, even when a university commits to sustainability reporting, the Student community is often unaware of it. To tackle this issue, we designed a research project to increase students' awareness of the University's efforts on sustainability through interactive tools. Concretely, the intention is to create participatory design and co-design paths with the students aimed to develop new interactive data visualization to visualize both data extracted from the sustainability report, and on the actions that the students can take to limit or reduce their impact in terms of carbon footprint. We intend to achieve this goal on two analytical levels, in the awareness of their interdependence: micro and macros.

The micro impact will be identifiable as awareness of sustainability issues and practices increases among the student community, and in particular, of the participants directly involved in the different phases of the project with tools such as interviews, participatory design, and public feedback. Also, the active involvement of the participants will be useful on two fronts: individual awareness and given-back awareness. Through the use of Participatory Design techniques, it will be possible to exploit the knowledge and stimuli offered by the participants and the products of their discussion tables. In this way, it will be possible to improve the research outputs (in particular, database and data visualization) and customize them to the community identity and specific needs of the campus and its population. Further, raising awareness of the individual could

positively impact collective sustainability. In fact, if each individual were to adopt more sustainable behaviors during daily life on campus, beneficial effects would also be found at a macro level.

The macro impact will result in raising awareness of sustainability practices at the university level (the consequence of the micro impact) and will be concretely attributable to the return of an updated dataset, interdisciplinary and integrated with those already existing and owned by the University of Bologna. The dataset, including data collected through qualitative and quantitative methods, will allow consolidating the validity, favoring its discussion of the official data on sustainability already existing (i.e., sustainability reporting) and reinvigorating the debate about the sustainability of the university community and the importance of the individual and his impact on the community and in the area. With the awareness of these new data, it will be possible to evaluate opportunities for innovation sustainable for the reality of the campus(es) or other wider realities, such as the local community.

As a case study, we focused on the sustainability of the University of Bologna. Starting from 2016, the University of Bologna has implemented a reporting tool that aims to provide a fresh perspective on measuring the university's efforts in achieving its sustainable development goals (SDGs). It employs an approach that effectively captures both the direct and indirect impacts generated by the university's core activities, including teaching, research, third mission, and institutional operations. The ultimate objective is to actively contribute to the attainment of the United Nations' 17 sustainable development goals.

In this paper, we present the results obtained by conducting quick interviews to investigate what sustainability means for students. The objective was to gather the common sentiment about the sustainability topic within the population of campus students. Eventually, the collected data found use in the informed co-design workshops, where interesting ideas were originated. We conclude the paper by discussing the obtained results, formulating guidelines, and presenting future work.

## 2 RELATED WORK

In recent years, sustainability is deeply discussed inside universities to reduce their environmental impact, looking also at the social and economic point of view to cover sustainability as a whole. That's why there is a growing body of work tied to sustainability practices also inside universities and campuses. In their literature review, Amaral et al. investigated the actions and practices carried out by several universities reported in the literature and identified eight categories: energy, buildings, water, waste, transportation, grounds, air and climate, and food [1]. Puertas and Marti analyzed the actions made by universities and proposed an indicator (DEA-GreenMetric), based on the UI GreenMetric World University Ranking, able to create a ranking of the universities examined. This indicator scored the universities based on five categories: energy & climate change, waste, water, transportation, and education & research [28].

Despite the quantity of work that exposes sustainability practices inside universities and the numerous actions taken inside the campuses, the university community is not necessarily aware of this even though their actions contribute to sustainability within

the university premises. These were the premises of the study carried out by Msengi et al., where they administered a questionnaire to university students to understand their level of knowledge and awareness. From their findings, the students' majority didn't know about the university's commitment and initiatives related to sustainability [24]. At the same time, the study carried out by Oltra Badenes et al. analyzed the level of knowledge and commitment concerning the SDGs to understand if the students were aware of the university's initiatives and their role in achieving sustainability [4]. From their analyses, they found out that students knew something about SDGs, but they were not aware of their role and impact in this context. In [17], Griffin et al. investigated how to raise sustainability awareness in a university to produce a change in young adults through a series of events. The authors adopted a Participatory Action Research (PAR) approach to directly involve the stakeholders.

It is not uncommon for students to be involved in the design of events, spaces, or even courses in the university context. For example, in [7], they were involved in a co-design session for the creation of improved spaces in a library, or in [18] were co-creators of a course syllabus. The collaboration between the different stakeholders benefits both sides, which is why, in [10], the authors focused on the approaches to create and support this partnership. In particular, they exploited a student-staff design thinking workshop and highlighted that co-creation can be a way of helping staff in finding new solutions to known issues.

Summing up, sustainability is a pressing issue addressed by universities around the world. Many universities have policies and initiatives to improve all three facets of sustainability (environmental, social, and economic) on the campuses. However, students are usually not aware of these practices and what they can do to have a direct impact on the sustainability of the campus and, more in general, in their local area. At the same time, co-creation and co-design with students are often used in the university context to create or improve something that can benefit the entire university community and solve well-known issues. Based on that, we proposed a 3-step process involving students in the co-creation of an app aimed to raise awareness of what the university is doing and what an individual can do in the sustainability context.

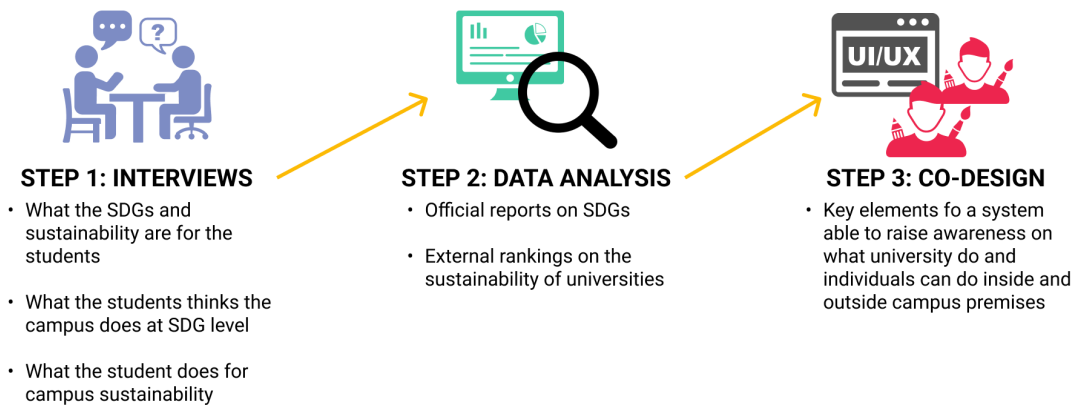
## 3 METHODOLOGY

Awareness can be tricky to evaluate. For this reason, we tackled awareness at two levels: micro and macro. To do so, we employed three main techniques. The first is semi-structured interviews, the second is data search and analysis, and the third is co-design.

After analyzing the resulting data, we condensed the two datasets into an informative booklet. This booklet was provided to the Co-Design participants. The intention was to furnish them with a common starting point for the co-design activity. In the following paragraphs, we go into detail regarding the 3 main steps of our research.

### 3.1 Step 1: interviews

To address sustainability awareness, we decided to use semi-structured interviews. The choice of semi-structured interviews as the main source of the investigation was made because of their flexibility,



**Figure 1: The three-step process carried out in this study.**

both respecting the predetermined questions of the protocol to explore all the pre-identified themes and letting space for further investigation around elements of interest that may emerge through the single interviews [5]. In fact, this approach helps build an informal conversation, permitting the interviewee to feel more relaxed and giving them the opportunity to talk about what they feel is relevant [29]. The informal tone of the interview also favors narrative and discussion of sensitive arguments (critics, authority, relationships with peers or other members of academia, or even emotions and topics that may result in embarrassment). Due to the nature of the interview setting (a university campus) and the interviewees (students), we opted for a smaller batch of questions to facilitate the participation of everyone. For this reason, we opted for what we called quick interviews. The interviews consisted of four questions and one final bonus request for a small drawing. The questions were:

- i) "What does sustainability mean for you?";
- ii) "How is sustainability manifesting at the campus?";
- iii) "What do you do for sustainability when you are on the campus?";
- iv) "Do you have any ideas on how to improve sustainability behaviors at the campus?"

bonus) "Could you draw something that represents sustainability here at the campus? In the process, if you would like, you can tell me about your drawing choice."

The quick interviews have the advantage of not being time-consuming for the interviewees, hence enabling us to ask for interviews during the students' break. Of course, by limiting time, we also limit the depth of the data. However, when the interviewees desire to expand on an argument, they are free to do so. Finally, these interviews' goal was to give us a general overview of the first-hand experience of the students' sustainable behaviors at the campus. For these reasons, we consider quick-interviews to be an effective tool in this context.

From the interviews, we wanted to extract the main elements of interest to structure an informative booklet. The booklet should be used to inform about the perceived experience of what sustainability

means in the campus's everyday life and how personal behaviors are affected by it.

### 3.2 Step 2: data search and analysis

The second step of our process wanted to provide the university community with real data made available directly by the University and other external sources that examine the performance of the various universities in terms of sustainability and SDGs. Adding more details, starting from the SDGs that emerged from step 1 (interviews), we extrapolated the corresponding data exposed by official sources. In this way, we were able to create a booklet showing on one side the perception of the community in relation to the SDGs they considered most relevant in the university and campus context and, on the other side, the official data.

The sources we considered for the official data are three. The first one is the official report made available every year by the University of Bologna to understand the contribution of different institutional activities towards the achievement of the 17 SDGs [9]. Starting from 2016, the report highlighted the direct and indirect impacts of the university's activities, broken down into four dimensions: education, research, third mission, and institution. The second source is the World University Rankings made by UI GreenMetric [15]. Starting from 2010 by Universitas Indonesia, this ranking evaluates green campus and environmental sustainability in terms of universities' environmental commitment and initiative. In particular, they exploited 6 dimensions: setting and infrastructure, energy and climate change, waste, water, transportation, and education and research. Finally, the third source is the Times Higher Education Impact Rankings [34]. Starting from 2019, this ranking analyses and evaluates universities in terms of SDGs and exploits four dimensions: research, stewardship, outreach, and teaching.

For the data, we considered the calendar year 2021, as it was the closest year with rankings and reports.

### 3.3 Step 3: co-design

After collecting qualitative data from the interviews and the following analysis, the third step of the process involved the university

community in a co-design activity. As defined by Sanders and Stappers, by co-design we refer to the “creativity of designers and people not trained in design working together in the design development process” [32]. The main goal of our co-design activity was the creation of low-fidelity mock-ups representing an interactive web-based application able to raise awareness of what an individual can do for sustainability on the university premises and inform on what the university already does in terms of sustainability and the SDGs.

We planned the activity to last 1 hour and a half and structured it as follows:

- **Introduction** (15 minutes): we presented to our participants the project and the goal of the activity, including a brief explanation of co-design and low-fidelity mock-ups. We also gave them some suggestions on what they could use to raise awareness (named data visualization, gamification [8], and eco-feedbacks). At the end of this phase, we divided the participants into groups of 3/4 people.
- **Co-design** (50 minutes): the actual co-design activity involving the creation of paper-based low-fidelity mock-ups. To give them a starting point, we provided them with some materials resulting from the first two steps (interviews and data analysis). In particular, we prepared three documents: i) a document summarizing the outcome of the interviews; ii) a document with the reports made by the University, with a specific focus on the dimensions that came out from the interviews and iii) a document with the external rankings mentioned in step 2.
- **Presentation and questions** (5 minutes per group): each group presented its mock-ups to the rest of the participants, who could ask questions.

## 4 RESULTS

### 4.1 Interviews

The interviews wanted to give us an insight into the perceived elements of sustainability on the campus, and, despite the limited amount of time requested for the quick interviews, the argument treated (sustainability and sustainability awareness) was effectively tackled in this time frame. We interviewed students of the University of Bologna on two different campuses (Cesena Campus and Navile Campus) during their spare time at the local cafeteria. Given the context, the quick interviews allowed us to find participants without occupying too much of their time. Each interview lasted between 4 and 11 minutes. We conducted a total of 21 interviews and a total of 36 interviewees.

The first interviews were conducted with one interviewee at a time, but this posed a difficulty in recruiting persons in the cafeteria. Students showed to be more inclined in accepting to participate in the interviews with a friend coming along. Hence, we conducted the majority of interviews with two interviewees at a time.

After analyzing the content of the interviews, we summarized the answers to each question:

i) the word “sustainability” makes the interviewees think about the future, circularity, the Earth and environment, conscious consumption, daily actions, self-sufficiency, taking care of public spaces, renewable energy;

ii) concerning the sustainability inside the campus, on one hand, the interviewees recognized the presence of waste sorting, facilities for refilling water bottles, and the fact that the cafeteria is plastic-free. On the other hand, the heating in winter is always very high even in empty rooms, the lights and the computers in the laboratories are often on, and the campus is a bit out of hand, and the transport is lacking.

iii) regarding the students’ actions inside the campus, they mentioned the sort of waste, the refill of the water bottle at the public water dispenser, the attempt to limit water waste in the bathrooms, and the use of public transport or bike to reach the campus.

iv) the interviewees had also some suggestions for increasing the sustainability inside the campus, like further investing in solar panels or other sources of renewable energies and being careful with the heating and power management. In terms of services, it would be great to have a wider selection of public transport to avoid reaching the campus by car. On a final note, they would like to see more initiatives for inclusion, like providing sanitary pads in the bathrooms.

bonus) the drawings of the participants were a visual explanation and summary of the answers to the previous questions. As shown in figure 2, the main aspects that emerged were: waste sorting, the idea of circular economy, the green and environmental aspect of sustainability, and the idea that everyone should collaborate to have an impact on sustainability.

The content of these interviews was interpreted through the lens of the SDGs. The main SDGs tackled were five: sustainable cities and communities (SDG 11) for the heating management and lack of spaces and social moments, responsible consumption and production (SDG 12) for electricity management (lights and PCs), climate action (SDG 13) in relation to sustainable transports, clean water and sanitation (SDG 6) considering the water waste, and gender equality (SDG 5) relating to gender perceptions of some degrees where a gender balance is missing. With the knowledge gathered from the interviews, we picked these SDGs as a starting point for the data search. With this material, we proceeded with the informed co-design by collecting the data in an informative booklet.

### 4.2 Co-design

For our co-design activity, we recruited 19 students enrolled in the “Mobile Systems Programming” class (Bachelor’s Degree in Computer Science). All the participants were aged between 20 and 26 years, and 4 of them were female. Considering the number of participants, we divided them into 5 groups.

**Group 1: H<sub>2</sub>unib0.** The first group focused on encouraging the use of water bottles to reduce the plastic around campus. In particular, they designed the home screen of the application with a water bottle in which the water level rises in relation to the percentage of students who use the water dispenser situated inside the campus. This is feasible through a QR code attached to the dispenser that the university community has to scan with the smartphone to start dispensing. After the scan, the individual has to log into the system with the university credential to be identified individually and update the visualization accordingly and raise the water level. Moreover, the number of water bottles actually distributed by the





Figure 2: Drawings made by the interviewees.

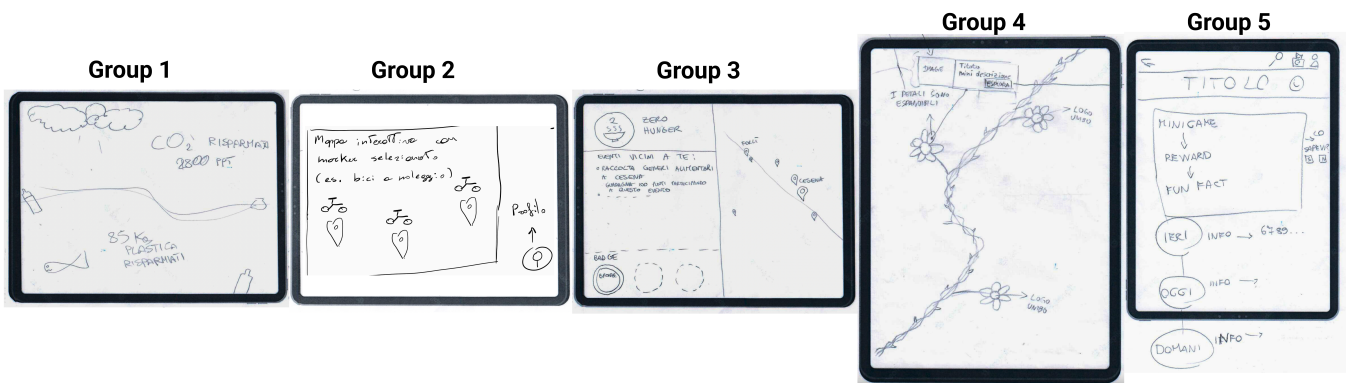


Figure 3: Mock-up of the five applications (one selected for each group).

university is also displayed on the home screen. The application also has two other screens: environmental impact and ranking.

The environmental impact screen has a double visualization, as shown in the first mock-up of Figure 3: in the top half of the screen, the sky is represented with clouds and the sun, while the sea is displayed in the bottom half. Moreover, this visualization conveys other two pieces of information: the quantity of CO<sub>2</sub> saved (for example, in industrial processes for creating plastic and bottles) and the plastic spared. The CO<sub>2</sub> saved is displayed in the sky, and its increase is visually tied to a more clear and bright sky with seagulls and birds. Concerning the plastic saved, the data (expressed in kilos) is visually tied to a more clean sea with happy fish and without floating plastic. The data about plastic and CO<sub>2</sub> are connected to the percentage of students who filled their own water bottle: every 10% increase you can see a less polluted sea and an increasingly clear sky up to an ideal 100% of students using only the dispenser with water bottles.

The third screen is the ranking: the group has designed a screen in which there is a sea at the bottom showing the total liters of water dispensed by the water dispenser. In fact, the group also thought about asking how much water the dispenser should supply

(instead of giving a single cut to the bottle) to avoid water waste. On top of the water, there is the ranking of the community with the first three having gold, silver, and bronze water bottle respectively, and the right part of the screen contains the top ten members. The ranking is calculated based on the water drunk to incentive to drink water more often, as a benefit to one's health.

**Group 2: UniboEcoMap.** The second group focused on encouraging more sustainable mobility to reach the campus premises. They thought about an application in which the community members can log in using the university credentials, and through these, a map is displayed with a focus on the current position of the individual. Then, the user can see all the ecological vehicles to reach the campus available in the current area, as shown in the second mock-up of Figure 3. Based on the vehicle selected, an individual can earn more points, for example, by going by foot or by bicycle s/he will earn 10 points each minute, going by bus 6, and going with a push scooter 5. Once a vehicle is chosen, the application shows the fastest route to the university with, below, a banner that presents data about the CO<sub>2</sub> saved during the trip and the kilometers traveled in real-time.

Pressing the banner takes the user to a screen with personal statistics, i.e., CO<sub>2</sub> saved, the number of kilometers traveled by each vehicle surrounded by bubbles, whose dimension is tied to the number expressed inside it. The pressing of a bubble gives a little hint explaining why it's good to use a specific vehicle, for example, riding a bike could be good for everyone's health and can keep the user in training, or the CO<sub>2</sub> saved means that we can breathe cleaner air.

The last screen of the application is the profile section, where the gamification elements are visible. In particular, the total points earned and the level of experience. Moreover, the users have a series of tasks (related to sustainable mobility) to complete in order to earn bonus points that can be spent, in the form of discounts or vouchers, at the bar or even in the vending machines. In addition, with the increase in the level of expertise, the users will be able to earn points faster to provide more incentive to use the application.

**Group 3: UniversityWheel.** The third group focused on creating an application based on all 17 SDGs. In particular, they imagined a competition between the different universities or even within the same university but between the different campuses by making a ranking revolving around the actions individuals take to improve on each SDG. The ranking aims to push users to do better in their daily lives to consequently stay higher than the others. They took a step forward and distinguished between "quantifiable" SDGs and "non-quantifiable" ones.

For the goals that are actually quantifiable, they have brought the example of SDG 12 (responsible consumption and production). They thought about a quest to fill the water bottle through the water dispenser on campus and earn badges which will help increase the score of their own faction (that could be the university or the campus). For SDG 11 (sustainable cities and communities), they focused on the transport issue and thought about a companion app on one's smartphone, which quantifies how many kilometers are covered by bicycles and other vehicles. These data would be then conveyed through the main application in the form of unusual and absurd units of measure which are easier for non-experts people to understand, for example, the CO<sub>2</sub> saved by the user or by the entire university faction can be transformed into the quantitative of rockets, barbecues, or cigarettes, and the distance traveled can be turned into the distance between the Earth and the International Space Station. The information about the user's progress in relation to the affiliation faction is visually represented by a tree.

For the goals that are more complex to quantify, the application will help the users pursue them by providing hints. For example, concerning SDG 1, which is no poverty, it could notify the users of areas nearby in which it is possible to donate second-hand clothes, or considering SDG 2 (zero hunger), it could notify the users of events nearby where it is possible to donate food. Participating in these events would also give the users some bonus badges, as shown in the third mock-up of Figure 3.

Moreover, the application will provide users with two types of quests for each SDG to gain bonus points: i) daily, that change every day, and ii) quantitative, for example, the hundredth time you use the water bottle gives you more points. For the quantitative quests, an icon is shown representing the percentage completed so far (for example, for SDG 12, the icon will be a water bottle filling up when

the user refills the water bottle). These quests are shown in the relative SDG screen, along with a map, with the events or the points nearby where it is possible to refuel the water bottle and the badges earned for that SDG.

Finally, the group thought about a public visualization at the campus level that can be visible through a kiosk at the entrance. The main screen would be focused on a large wheel with 17 areas representing each SDG, and with a click on each of them, the related information, articles, and scores are visible in real time.

**Group 4: FlowersApp.** The fourth group focused on designing an application involving all 17 SDGs. In particular, they imagined a homepage with, at the center, a climbing plant with 3 flowers, as shown in the fourth mock-up of Figure 3. The center of each flower contains the university logo, and the user can expand each petal (17 in total, one for each SDG) just by touching it. The expanded version of the petal is a pop-up showing the relative SDG image, its title, and a short description to increase knowledge on the topic.

From the pop-up, the user can go to a new screen representing the SDG in detail. Specifically, the users can see not only the SDG number, title, and description (already in the pop-up) but also other two fundamental information. The first one is what they can do for that SDG, in order to improve their behavior in their daily life inside and outside the campus premises. The second one is what the university is doing to pursue that SDG. This section also includes common graphs, such as bar charts and pie charts, to better convey the textual information. The last section of this screen is a questionnaire where the users have to declare what they have concretely done to accomplish the SDG and answer some questions related to the SDG topic. By completing the section, the user will obtain some points. This is possible through a login necessary to use the application.

The earned points are visible on the profile screen. This screen includes a line chart to display the user's progress in terms of total points and a ranking to encourage the use of the app and consequently lead him/her to do something concrete for sustainability. In the profile, the user can also see how to earn extra points, for example, by answering daily questionnaires and scanning a QR code positioned in the PoI of the campus to discover more about sustainability issues and practices.

**Group 5: AlmaHUB.** The last group focused on an application that encloses all the 17 SDGs and identifies a single user with a login through the university credentials. The credentials would also allow a ranking among friends and create healthy competition between users. The main screen will display the 17 goals in the form of cards, and once clicked, each card will have a small animation related to the representation of the goal itself. For example, they thought of a bowl being mixed for SDG2 (zero hunger). To earn points, they imagined the possibility of accessing the camera to scan a QR code attached to the Point of Interest related to sustainability action inside the campus premises (e.g., the water dispenser or the bar). After doing a "green" action, the users will scan the code and see the liquid level inside the relative card rise.

Accessing the single card will bring the users to another screen with a very simple mini-game that deals with the central topic of the goal, as shown in the last mock-up of Figure 3. The mini-game should not be complicated but should entertain the users. At the

end of this, there would be a reward as a form of gamification mechanism and various fun facts regarding the topic. Moreover, for each SDG, there will be a small interaction with the users, asking them if they already knew the topic and were interested in it. Under the mini-game, a vertical timeline is displayed with data about the day before, today, and the day after, in which it is possible to discover in the past what the university had done according to the SDG, what it is undertaking to do and what are the future challenges and goals.

Finally, the last screen designed is the profile section with the classic profile photo, earned badges, and all the unlocked achievements. They have also thought of two types of achievements: i) the daily ones, which can therefore be unlocked every day, and ii) the weekly ones to see how much the user has contributed for each SDG and also keep a winning streak to encourage “green” action in everyday life and perseverance. Below the badges and the achievements, they designed a section with graphs, like histograms in the form of trees rather than pie diagrams, which are actual pies perhaps expandable, instead of showing only a value that could be boring. The last section of the screen is a leaderboard with friends to have a mutual stimulus to do better.

## 5 DISCUSSION

Our three-step process wanted to respond to our RQs and highlight the key data and elements a system should have to raise awareness of what an individual can do for sustainability inside and outside the university premises and inform on what the university already does regarding sustainability and the SDGs. The awareness is particularly relevant since we want to increase sustainable behaviors in individuals’ daily life at the micro level to have a direct impact at the macro level.

We analyzed the process results through six macro-area (displayed in Figure 4) to highlight the key aspects of each of them.

Starting from the focus of the applications, our initial idea was to create a system showing information for all the 17 SDGs, but we were afraid of the cognitive overload caused by the interface [6]. However, the results from the co-design confirmed our idea, as 3 groups created a hub for all the SDGs, and another group proposed an expanded version of one SDG but stated that the idea was to replicate it for all 17 goals.

*Data Visualization and representation.* Analyzing the five applications, we noticed that all of them used data visualization elements to represent the impact made by the individual or by the university. This did not surprise us as data visualization is often used to increase knowledge and awareness in relation to sustainability issues and promote more sustainable behaviors [13, 30]. Analyzing the applications under the lens of data visualization, we can divide them into two groups. On one hand, we have some commonly used and well-known graphs, such as maps, bar charts, line charts, and pie charts. On the other hand, we have the transformation of data into commonly used vivid images and objects, especially related to the environmental impact. Concerning the images, we had a sea with fish and a sky with birds which show data converted into a potentially real situation. If we focus on the objects, we have water bottles, trees, or plants, which are the main symbols that

come to mind when we think about sustainability. These representations are in line with the data humanism approach proposed by the information designer Giorgia Lupi [20]. This is valuable also for the textual representation of the data, which also needs to be converted into something funny or more relatable to make the number more comprehensible, as proven by group 3 which turned, for example, a numerical distance expressed in kilometers into the distance between the Earth and the International Space Station.

*Gamification.* Analyzing the five applications, we noticed that all of them used gamification elements, often in combination with eco-feedback to encourage more sustainable behaviors. This did not surprise us, as in literature there is a body of work analyzing the relationship between gamification or gamified application and pro-environmental behavior [3, 33, 36]. Examining the applications, we can distinguish three groups of approaches. The first one is the competitive approach used by three groups where the individuals should compete with each other in order to climb the ranking. The second one is the cooperative approach, where individuals of the same faction or campus collaborate to increase the ranking of their team. This approach was used just by one group. The third approach is not based on competition, but it is tied to points to obtain discounts or vouchers, and it was exploited by just one group. These findings are generally in contrast with the study made by Morschheuser et al. [23]. In particular, they found that, in crowdsourcing systems, a cooperative approach with competing teams could be better than a competitive one where the competition is just between individuals. Despite that, in our case study, just one group chose this approach.

*Data.* As stated by Verbong in [35], a user can have various roles in sustainable innovation: they can be active or passive, and they can work towards sustainability as individuals or as part of something more complex, helping or obstructing the innovation. One of the goals of the applications resulting from the co-design phase was to make the users active players in this innovation, regardless of whether they act alone or in a group. As shown by all the applications, to achieve this goal, it is fundamental showing the data produced by the single individual to display the direct impact he or she can have on sustainability. Showing this data also highlights that individuals have the power and responsibility of improving the context where they live and encourage pro-environmental behaviors. This is also a way to fight eco-powerlessness, as the fear and feeling that one’s actions in daily life have little impact on wider issues expressed especially by the lower classes [19].

*Technology.* Concerning the technological aspect, what came up from four of the five applications is that a mobile or web application could not be enough to interact or engage with users. For example, one group suggested a companion app to monitor the users’ steps, suggesting a multi-device application. This is in line with a body of work analyzing multi-device applications and suggesting guidelines in the area of HCI [31, 37]. Moreover, the interaction can be also with other objects, such as QR codes, to increase users’ engagement [16, 27] and appeal to users’ curiosity in discovering new content [25].

GROUP	FOCUS	DATA VISUALIZATION	GAMIFICATION	DATA PRODUCER	TECHNOLOGY	LEARNING STRATEGY
1	Reduce plastic waste	Water bottle Sea with fish Sky with birds and seagulls	Ranking	Individuals	QR code	Visualization
2	Sustainable Mobility	Map Bubbles	Points	Individuals	/	Hint
3	17 SDGs	Water bottle Tree	Ranking Points Badge	Individuals	Companion app	Hint
4	17 SDGs	Climbing plant with flowers Bar chart Line chart Pie chart	Ranking Points Badge	Individuals University	QR code	Questionnaire Fact
5	17 SDGs	Liquid level Tree Pie	Ranking Badge	Individuals University	QR code	Questionnaire Fun fact Minigame

Figure 4: The key points of the application idea of our five groups.

*Learning Strategy.* The application should also raise knowledge on sustainability issues and practices inside and outside the university. To do so, we found different approaches in the five applications. For sure, there should be an explicit component to make the users learn something. This component can be of various types depending on the level of engagement with the user. It can be a simple visualization, where the users can learn the impact of their actions just by looking at a visual image of sky and sea, or it can be a static hint or fun fact explaining an SDG or relative action to take (as exploited in two groups). To increase the level of engagement, we can exploit questionnaires or mini-games to make the users more involved. From our analysis, we were not able to understand the best method to raise knowledge, so it should be tested and evaluated with the real application.

*Guidelines.* Summing up, from the five applications designed, we extrapolated the main feature of a system with the goal of raising knowledge and awareness on two aspects: i) what the university is doing in relation to sustainability and SDGs; and ii) what the individual can do inside and outside the university premises. This kind of system should:

- show information about all the 17 SDGs to convey a more complete idea of what is sustainability and what can be done to improve it in daily life;
- exploit data visualization techniques that transform data into more relatable images or information;
- exploit gamification strategies to engage the university community relying on the sense of competition between individuals;
- show individual data to show the impact each one has and to remove the eco-powerlessness feeling;

- exploit other technologies other than the main application to increase engagement and usage in daily life;
- exploit at least one explicit learning strategy to make the users learn directly through the system's usage.

## 6 CONCLUSION

In this paper, we describe a 3-step process to extrapolate some guidelines for the creation of an interactive system that could eventually raise knowledge and awareness on two aspects: i) what the university is doing in relation to sustainability and SDGs; and ii) what the individual can do inside and outside the university premises. In this process, we involved the target users of the system to co-create an application with data visualization and gamification as the main elements. An application of this kind should be combined with other technological components to increase interaction and engagement with users and should contain some fun and interesting hints or facts to be displayed to the users to increase their knowledge of the 17 SDGs. As future work, we plan to implement a multi-device application exploiting the results of the process to verify their actual effectiveness and evaluate the users' awareness after their exposure to the application.

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