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Designing interactive infographics to stimulate environmental awareness: an exploration with a University community

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Abstract The Sustainable Development Goals (SDGs) are a universal call to action addressed not only to governments but also to businesses and civil society. In this scenario, Universities play a key role in achieving the SDGs and, also, in creating awareness about these global issues. As an example, the University of Bologna is carrying out several initiatives related to sustainability matters. Considering, in particular, the environmental dimension, the University undertook different strategies to reduce the waste of paper, embracing the dematerialization and paperless movements. To make these initiatives visible to the University community and to increase awareness about these issues, we designed a system that intends to provide data related to the implications of such initiatives in terms of paper waste avoided and benefits for the environment, to be exploited using different devices. In particular, this study focuses on the design and the evaluation of two infographics, conceived by two different groups of experts and researchers: one "animated" and one "aesthetic". The evaluation intends to present the differences in terms of perceived design and informative dimensions, with the final aim to present insights on the design of infographics able to foster awareness, targeting specific communities.

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1 Introduction

Humanity is facing several global challenges, including those related to poverty, hunger, inequality, climate change, decent employment, and peace and justice. In 2015, the general assembly of the United Nations defined a universal call to action, titled *Transforming our world: the 2030 Agenda for Sustainable Development*, which aims to address these major challenges, in order to achieve a better and more sustainable future for all [35,31]. Such a roadmap groups the issues in 17 Sustainable Development Goals (SDGs), each one presenting targeted actions to mobilize global efforts to end poverty, protect the planet and ensure that all people enjoy peace and prosperity, by 2030 [35,31].

The SDGs seek worldwide actions among governments, businesses, and civil society. Since its definition, the agenda was adopted by 193 states at the United Nations and all governments worldwide have agreed to its goals. Nonetheless, its success relies heavily on actions and collaborations by all actors. Accordingly, fundamental is the effort of companies and institutions to align their strategies as well as to measure and manage their contribution to the realization of the goals [13], as stated by Ban Ki-moon, Secretary-General: "Companies can contribute through their core activities, and we ask companies everywhere to assess their impact, set ambitious goals and communicate transparently about the results" [13]. Likewise, universities in Europe and around the world are crucial to global sustainable development [5].

In this context, the University of Bologna puts in place different strategies and actions to achieve the SDGs, focusing, in particulars, on four dimensions: teaching, research, third mission, and institution [9]. At the same time, the University is undertaking actions to reduce its impact on the environment. One of these actions aims to reduce the use of paper, embracing the *paperless* concept [24]. The idea behinds this concept is really simple: attenuating the papermaking environmental impact by managing documents (creation, modification, storage and retrieval) only (or mostly) in digital form, and the impact of this strategy has been investigated in different contexts, such as office [37, 1], classroom [4,15], University and campus [26,29,44], and society [33,22].

The paperless movement has a two-fold significant positive effect on sustainable development. Firstly, it allows to promote sustainable use of terrestrial ecosystems and sustainably manage of forests, combating deforestation (according to the SDG 15). Indeed, forests are a critical foundation to assure sustainable development, reducing the risk of natural disasters, including floods, droughts, landslides, and other extreme events, and mitigating climate change through carbon sequestration, contributing to the balance of oxygen, carbon dioxide and humidity in the air and protect watersheds, which supply 75% of freshwater worldwide [34]. Moreover, forests are crucial for food, water, wood, energy, biodiversity, and health [38], nonetheless, they are experiencing

deforestation and degradation. From 2000 to 2013, the global intact forest landscape area decreased by 7.2%, a reduction of 919,000 km^2 [41]. People cut down 15 billion trees each year and the global tree count has fallen by 46% since the beginning of human civilization [14]. The paper production is one of the main players behind deforestation: 50% of the world's industrial logging is transformed into paper [6]. In fact, despite we entered in the digital era, the global demand for paper products has actually increased in the last decades (with a global increase of the 3% per year), evidenced by the more than 350 million tons produced annually [8,47,16].

Secondly, reducing the amount of paper used will benefit the environment since the papermaking process is toxic, resource-intensive, and uses chemicals and pollutants that are creating major health issues and environmental degradation. Moreover, the process required to obtain paper pulp (the primary material used for papermaking), together with the disposal of paper waste products are the major contributors to greenhouse gas emissions [47]. As a consequence, the pulp and paper industry is one of the largest energy consumers, greenhouse gases (GHG) and pollutant emitters among manufacturing industries. Studies have assessed that the production of one ton of paper results in circa 950 kg of carbon dioxide (CO_2) equivalent greenhouse gases (GHG) emissions (on average) [48].

In this scenario, technology, and in particular, interactive systems, have been proven to be a useful tool to increase user awareness about sustainability topics and strategies, and, consequently, to foster behavior change [20]. Drawing on previous studies on sustainable HCI (e.g., [19,17,18]), Data Visualization (e.g., [42,25,40]), and public installations to increase awareness (e.g., [51,7,27]), we designed a system that exploits different technologies, mixing digital and reality (as presented in [43]). Here, we detail the design and the evaluation (engaging people from the University community) of one specific component of the system: the web-based application to visualize interactive infographics. In particular, this study focus on the evaluation of two different interactive infographics, designed to exploit different styles and techniques, to extract insights related to the design of infographics to increase awareness about sustainability issues.

The remaining of the paper is organized as follows. We begin with an overview of previous studies and projects that inspired our approach in the context of information visualization to communicate sustainability issues and engage communities. Then, we briefly describe the design, the architecture and the implementation of the whole system, focusing, in particular, on the design and implementation of the two web infographics. The evaluation, involving users from the University community, and the related outcome are then presented and discussed, together with limitations. Finally, we conclude the paper with final remarks and future works.

2 Related Work

Several scholars investigated the use of interactive visualizations, including both data visualization and infographics, to provoke reflections on sustainable behaviors and behavior change. For example, in [46], the authors present the use of an infographic (the Double Pyramid of the Barilla Center for Food and Nutrition) to promote healthier and more sustainable food consumption. After an evaluation phase, results show that nutritional messages do have a significant influence on users involved in the test [46].

In [28], the authors investigated the intuition to design for persuasion. In doing that, they designed two ambient displays as desktop widgets, representing a user' computer usage time, but in different visual styles: a *coralog* (because coral reefs are currently being destroyed by the rapid increase in the amount of CO_2 dissolved in the ocean and the elevated sea surface temperatures), and a *timelog*.

Holmes designed artworks that display the real-time usage of key resources such as electricity in order to prove if such an approach can offer new strategies to conserve energy in the home and workplace [25]. In particular, the media art, called *7000 oaks and counting* is composed of a sequence of animated clips using a series of tree images that correspond to the carbon loads in the building. The trees reflect seasonal variation: fall, winter, spring, and summer [25].

The *Imprint* project aimed to bring data into discussions about paper usage and waste [42]. The project displays in a touch-sensitive LCD display 5 visualizations: i) a tag-cloud that collects commonly printed words and can serve as a summary of the popular concepts; ii) a visualization to show how popular a given community member is; iii) a visualization that clusters workers based on the documents they printed; iv) a pie chart which aggregates the time that printers are working versus their idle times; v) a visualization depicts the total amount of energy used to power Imprint itself [42].

In [45], Rist et al. have focused their study on various types of interactive energy visualizations, with particular attention on how the user behavior and, consequently, his/her energy consumption, changes on the basis of the exploited visualization. They used the Fogg Behavior Model ([20]) to categorize interactive visualizations ranging from charts to pictorial or gamified visualizations. They aimed to prove that visualizations can increase users' awareness and motivate them to reduce their energy consumption.

Another project presents the visualization of an augmented bin with the relative facebook application that puts users in front of their conscious and unconscious behaviors concerning their waste management [12, 49]. This study insists on the social component, which relies on every user's desire to be accepted by the community and his/her sense of guilt and shame once he/she realizes his/her waste. To improve users' awareness and their behavior, they use an approach based on gamification with a weekly visualization for every user. This visualization displays the user's recycling achievements and the food waste savings in the form of a tree and gold bars.

To engage public participation and to make them aware of not only sustainable issues but also the complexity of sustainable development, in [2], Antle et al. designed and developed a game on a multi-touch interface on public venues. They used the concept of collaborative learning to create a game for seven years old and older people to show them the complexity of balancing the environment and human needs. To verify that the gameplay leads the user to be aware of the difficulties in sustainable development, they used a survey based on 13 questions [3]. The idea of using a public display for people to interact and to increase their awareness is not new. Similarly, in [36], Odom et al. present the design and the implementation of an Eco-Visualization in situated displays. The context was a campus community where they implement a dynamic visualization to create competition between dormitories. The main goal was to change the students' long-term behavior about energy and resource consumption. They believed that situated displays could create a more engaging experience, which can lead to better consumption habits.

An interesting project is the *Go and Grow* system that presents a living visualization to increase users' awareness and to ensure them a more active lifestyle [10]. The system uses personal data, like steps taken from a tracker, to properly water a living plant. Also, the authors have provided an online dashboard to have an alternative way to visualize the data. The system wanted to prove that abstract or living visualizations are more emotionally engaging and, accordingly, more capable of produce a behavioral change.

The artwork *A Conversation Between Trees* has been designed with the purpose of establishing a live connection - or conversation - between a distant tree in the Atlantic forest and a local tree at each venue (one of the three selected arts centers located in different UK forests) [27]. The artwork visualizes environmental sensor data, captured and streamed live from each tree, on two large displays. Between these visualizations is located the "climate machine", an unusual device that visualizes recorded and predicted global CO_2 levels by slowly burning circular graphs onto large circular disks of recycled paper. Moreover, visitors can also experience a walk in the local UK forest during which they can use a mobile phone to capture and visualize images of the forest and answering questions about their feeling of being in the forest [27]. This installation represents an example of a piece of "ecologically engaged art" to open up, stimulate and frame the public debate around sustainability [17].

All these examples provide the powerful of interactive visualization to promote sustainable behavior. Inspired by them, we designed our system.

3 The System Walkthrough

3.1 The context

In accordance with the paperless and dematerialization movements, during the last years, the University of Bologna employed several strategies to reduce the consumption of paper. Due to the University size, which counts a community of

more than 92.000 individuals including students, faculty, and staff, spread on 5 cities, each initiative has a strong impact on sustainability. This impact can be calculated in terms of: i) number of trees "saved" (i.e., the amount of wood that would be required to produce the given amount of paper); ii) kilograms of CO_2, a value that measure the CO_2 from burning fossil fuels, methane from paper decomposing in landfills and short-lived climate pollutants, including forest carbon storage loss from logged forests. These values have been estimated considering, for each paperless action, the number of paper sheets not used thanks to the dematerialization strategies, and the "Paper Calculator"[1], a web-based tool which allows calculating the estimated environmental impacts of different paper choices using a science-based methodology grounded in life cycle assessment.

Moreover, to make the effort more tangible to its community, the University governance decided to plant new trees in terrains nearby two newly built campuses; the number of trees that will be planted represents a percentage of the total number of saved trees avoiding the use of paper. This action has two positive effects: it allows the University community to enjoy a tangible result of the paperless strategies, becoming more aware of the University effort, and, moreover, the trees will benefit the Campus area, in terms of pollution (CO_2 sequestration) and noise attenuation capability.

3.2 System overview

To stimulate reflections related to the sustainable strategies undertaken by the University of Bologna, we designed and implemented a system that takes advantage not only of online rich contents related to the paperless effort (exploitable using different devices) but also of the outdoor new green areas that will be created, so as to collect location-based measures and provide personalized visualizations. The whole system comprises different components (employing different technologies), as depicted in Figure 1 and briefly presented in the next paragraphs (more details can be found in [43]).

The system includes a sensors infrastructure deployed in the Campus green areas where the trees will be planted to collect data of environmental conditions such as particulate matter (PM 1.0, PM 2.5 and PM 10), carbon dioxide (CO_2) and carbon monoxide (CO), nitrogen dioxide (NO_2) and ozone (O_3), formaldehyde, temperature, related humidity, and air pressure. All these sensors are encapsulated in the CANARIN II sensors station [50]. The idea is to use these data to provide up-to-date information about the environmental conditions, through the online contents (exploitable from different devices) and an in-situ installation.

Using the gathered sensors data, we intend to provide an in-situ public installation in the Campus green area, equipping a tree with an RGB color LED string lights. The color of the lights will change accordingly to the level

[1] https://c.environmentalpaper.org/

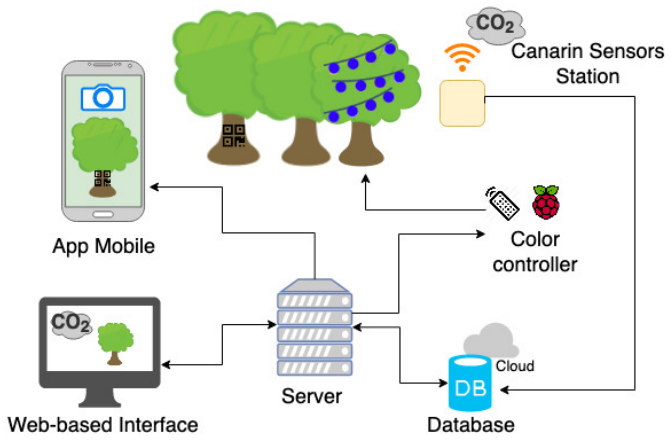

Fig. 1 The system architecture

of pollution detected in real-time (e.g., "red" if the detected pollution level is critical; "blue" if the detected pollution level is in the range considered as not critical but not so low; and so on).

To link the planted trees with the digital contents of the web application, we prototyped a mobile application (both for Android and iOS devices) able to read specific Qr-code markers (placed on the proximity of the tree) and provide AR information about the real-time environmental condition (i.e., the pollution level) together with details about the paperless actions the University is undertaking, while exploring the campus green area.

The last key component in our developed system is represented by the web-based interface that is the focus of this investigation and is presented in detail in the next section.

4 The Web-based Interactive Infographics

This work is unfolding alongside a growing interest in using ICT and information visualization to promote sustainable development. Technology has been proven to be a useful tool for increasing user awareness about sustainability topics and for fostering behavior change. This is particularly true considering interactive systems, that, providing targeted information, can lead to a process of decision making, persuading and influencing the users [20]. In this scenario, Information Visualization (InfoVis), defined as the use of visual representations, provided through the use of computers, to amplify the user's cognition by leveraging human visual capabilities to make sense of abstract information, has become increasingly relevant [21]. The information is displayed using attributes, such as color, shape or size, specifically designed to reveal new data or to highlight relationships between the data that may not be noticed at first sight [30]. Interesting is the specific case of infographics (information graphic)

where elements of data visualization are combined with design to disseminate data in an attractive and aesthetic fashion [23]. The final aim is always the same, making sense of data and increasing awareness about a specific issue.

Along the same lines, we decided to exploit information visualization, and, in particular, infographics, to provide the informative rich contents related to the different initiatives the University of Bologna is carrying out in favor of the dematerialization process and in accordance with the paperless movement. To this end, two interactive infographics have been designed and evaluated to exploit different techniques and styles.

4.1 The design process

To design the infographics we carried out two distinct brainstorming sessions:

- one involving four researchers in Human-Computer Interaction (HCI) and data visualization at the department of Computer Science, University of Bologna (CS group);
- the other one engaging three researchers and experts with background in storytelling, and web and graphic design from the Interactive Technologies Institutes, Madeira (ITI group).

Both the sessions lasted circa two hours and a half and began with 10 minutes of introduction, to explain the context and the available data. In particular, we asked them to design an infographic including the following information (as design constraints):

1. the number of years the University is carrying out the paperless initiatives;
2. the three main categories used to group the paperless initiatives, i.e., process innovation, dematerialization and digital communication;
3. for each category, an overview of the specific implemented projects;
4. for each project: name, description, number of sheets not used, number of "saved" trees, CO_2 not produced avoid the papermaking process and stored by the saved trees, and the number of years such an activity has been running.

At the end of the two sessions, each group selected one idea to be refined and implemented. From the CS group, the emerged infographic mainly exploits interactivity and animations, using the metaphor of leaves on a tree (where each leaf - circle - represents a project), in an incremental single-page layout; while, from the ITI group, the selected infographic mostly exploits storytelling and aesthetic, recalling correlations between the saved trees (as the result of the paperless actions) and the new Campus green areas, in a horizontal layout, where the story is told using different static frames. For these reasons, we named the first one "Animated infographic" and the second one "Aesthetic infographic".

4.2 Infographics implementation

Both the designed infographics have been implemented exploiting well-known web-based technologies, such as HTML5, CSS3, and Javascript-based libraries. Considering the "Animated infographic", we also take advantage of JQuery UI[2] and D3.js[3] to manage the animations and positioning the virtual leaves, and frameworks, as Bootstrap[4]. All used images are in scalable vector graphics (SVG) format.

Both the infographics implement a three-layer logic to present content: 1. in the main page it is possible to see an overview of all the categories, 2. then, it is possible to select a category and to have an overview of all the projects in such a category, and, finally, 3. data related to a specific project are presented when selected. The main three screens of the two interactive infographics are presented in Figure 2 and Figure 3, respectively. In particular, in both the figures, the first screenshot presents the main page with the general overview on the three categories, the second one presents the overview of the projects related to the "dematerialization" ("Dematerializzazione" in the Italian language) category, and the last one presents details about the "Digital thesis" ("Tesi digitali" in the Italian language) project.

As depicted, the main page of the "Animated infographic" (on the left of Figure 2) shows the metaphorical tree with the projects-leaves, the three macro-categories, and the timeline. The user can then select one category (highlighted with the yellow color in the central screen in Figure 2), so as to activate (using AJAX) the information container at the bottom of the page. Finally, the user can select one single project, to visualize its details (on the right of Figure 2). This interface exploits an incremental single-page layout for a vertical-based navigation experience. Moreover, to engage users, we exploited a combination of illustrations, text and other elements that are animated to add movement and catch the user's eye. The same three layers logic is employed in the "Aesthetic infographic", where, instead, the interaction is based on three static (not animated) frames that provide the different levels of details, in a horizontal-based navigation fashion (as shown in Figure 3). In this infographic, the main idea is to show the green area of the campus (with the campus building in the background), creating a narrative link between the paperless initiatives and the planted trees in the renewed green area.

5 The evaluation

Developed the two infographics, we engaged users in an evaluation, as presented below.

[2] https://jqueryui.com/
[3] https://d3js.org/
[4] https://getbootstrap.com/

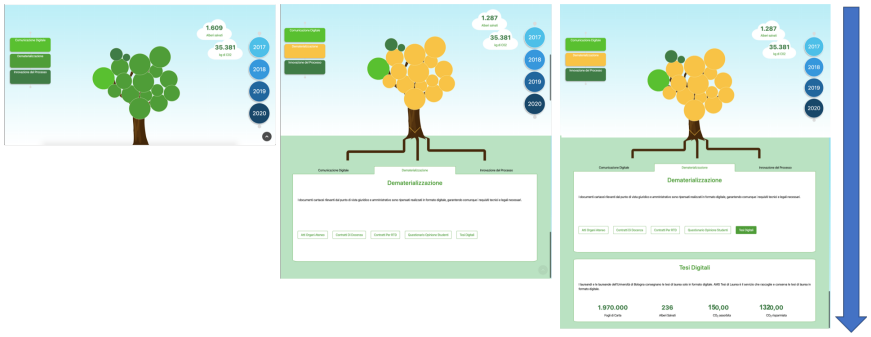

Fig. 2 The "Animated infographic" vertical-based navigation

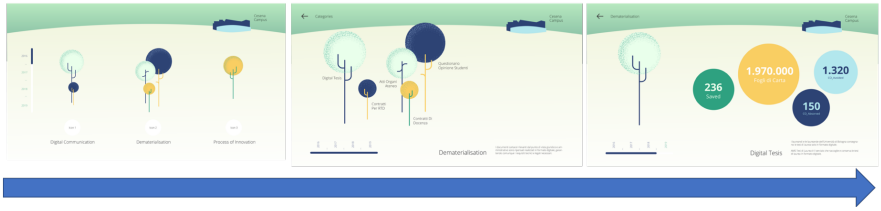

Fig. 3 The "Aesthetic infographic" horizontal-based navigation

5.1 The methodology

To evaluate the two infographics, we developed an online questionnaire (using Google Forms), in order to collect feedback from the University community (including undergraduate, graduate and Ph.D. students, faculty and staff members), who will benefit from the visualizations.

The issue of evaluating infographics has been investigated in different studies (see, for example, [39,23,52]). As a framework to drive our evaluation, defining which dimensions to analyze, we put into practice the one presented in [32]. In such a study, the authors present a user study conducted on two versions, i.e., one interactive and one static (a simple snapshot of the interactive one) of a series of three infographics related to weather forecasts, university ranking, and countries well-being. Going through a detailed process, the authors observed that users expressed clear preferences for the interactive infographics. Drawing on this outcome, the goal of this study is different: comparing two different interactive infographics that differ in the design and graphic style, and level of interactivity and storytelling, while presenting the same data, to detect any significant difference in their perceived characteristics. Nonetheless, we opted to draw on their study and to employ the resulting model for the assessment of the different qualities (inspired by the "Visualization wheel" [11]) as the framework for our investigation. In particular, for each infographic, we were interested to investigate: i. six **information quality dimensions** (i.e., sinteticity, clarity, informativity, intuitivity, attractiveness, elegance), measured using a 6-points ordinal Likert-scale (1 -

strongly disagree; 2 - disagree; 3- somewhat disagree; 4 - somewhat agree; 5 - agree, 6 - strongly agree); and ii. six **design quality issues** (i.e., essentiality/redundancy, abstraction/figuration; functionality/decoration; density/lightness; originality/familiarity; multidimensionality/monodimensionality), measured using a ordinal Likert-scale from 1 (first dimension) to 9 (second, opposite, dimension) (e.g., 1 - essentiality to 9 - redundancy and 5 - neutral). All the details about these dimensions and issues are presented in Locoro et al. study [32].

The questionnaire encompassed four sections:

1. General info: items related to the users, such as gender, age, background, role inside the University community (i.e., undergraduate, graduate and Ph.D. student, faculty member, staff member);
2. Animated infographic: we provided respondents with screenshots of the infographic, and we asked them to evaluate the dimensions of interest answering to the information quality items plus the design quality items. Moreover, we provided them with the link to the working infographic and we asked them to answer to contextual questions (two), looking for the answers interacting with the infographic. An example of the question is: "How many paper sheets have been avoided thanks to the digitization of the *Tesi Digitali* project?";
3. Aesthetic infographic: this section comprises the same items of the previous one, considering the corresponding screenshots. Also in this case, we provided respondents with the working link to the infographic and we asked them the task of interacting with the infographic and writing the answer to the proposed two questions (different from the ones presented in the previous section);
4. Awareness questions: to collect preliminary insights of the relevance of such infographics considering the possibility to use them as a tool to foster environmental awareness, we asked users if they feel more aware about environmental issues after having interacted with the infographics (to be answered by selecting a value on a 5-points ordinal Likert-scale - strongly disagree; disagree; neutral, agree, strongly disagree).

For each of the information quality items and design quality issues, besides the official term, some synonyms or a definition were presented to the respondents, in order to disambiguate their intrinsic meaning as much as possible.

We provided all respondents with the same sequence of questions, while the items for each question were presented in a randomized order.

5.2 The participants

45 University members answered the questionnaire, recruited inviting CS students enrolled at the Web Technologies class (Bachelor's Degree in Computer Science), and faculties/staff members, using the snowball sampling method. All respondents are part of the University of Bologna community. The participants sample is characterized as follows: 23 (46%) female and 22 (44%)

male, with age ranging from 19 to 64, with 29 (64%) with an age between 19 and 25; 13 (29%) undergraduate students, 18 (40%) graduate students, 3 (7%) Ph.D students (for a total of 34 students out of 45), 7 (15%) Faculty members and 4 (9%) staff members (for a total of 11 "non-students"). The students are mostly from CS (26); the remains are enrolled in different degrees, including environmental sciences, psychology, education, economics, and marketing.

6 Results and discussion

The collected data were analyzed to highlight emerging insights, comparing the two infographics and the different dimensions, grouped by information quality issues and design quality issues.

Before performing the below-presented analysis, for all the statistical tests, we applied standard procedures of statistical hypothesis testing by adopting a confidence level of 0.95 and a significance level of 0.05. In particular, we computed Pearson Correlation between the dimensions (expressed with a value from -1 - negative correlation, to +1 - positive correlation), to test the null hypothesis: *there are no significant correlations between the proposed dimensions*. Results show a positive correlation with all the couples of dimensions, with a p-value < 0.05.

6.1 Information quality issues analysis

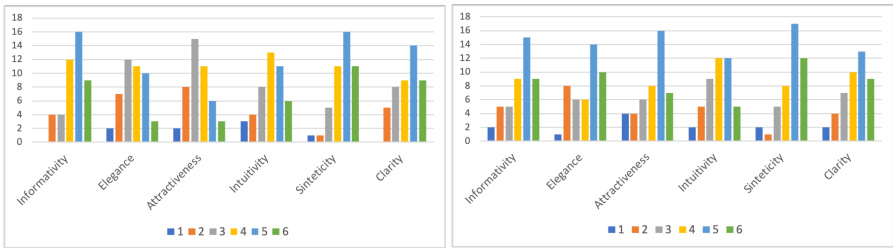

Fig. 4 Information quality dimensions. The distribution of the respondents' value (from 1 to 6): animated infographic (right) and aesthetic infographic (left)

Figure 4 displays the values assigned by the participants to the two infographics, considering the information quality issues analysis. It is possible to observe that the majority of participates considered both the infographics informative, clear, and synthetic. In particular, aggregating the "positive" answers (4 - somewhat agree, 5 - agree, and 6 - strongly agree), we can notice a similar trend for the two infographics and the following dimensions (considering the animated and the aesthetic infographics respectively): informativity, 82% and 73%; intuitivity, 67% and 64%, sinteticity, 84% and 82%; clarity,

71% and 71%. Besides that, two interesting issues emerged: in general, the aesthetic infographic appears more elegant and attractive if compared with the interactive one. In fact, 69% of users positively agreed with the attractiveness dimension of the aesthetic infographic (versus 44% if focusing on the animated infographic). Moreover, the elegance dimension provided interesting insights. If we check the aggregate amount of positive values, we have that 53% and the 67% of respondents found the infographics (the animated one and the aesthetic one, respectively) elegant; but if we focus on the values obtained by the animated one, it is possible to notice that 31% of users selected strongly agree and 22% selected agree, solidly asserting the elegance characteristic of such an infographic.

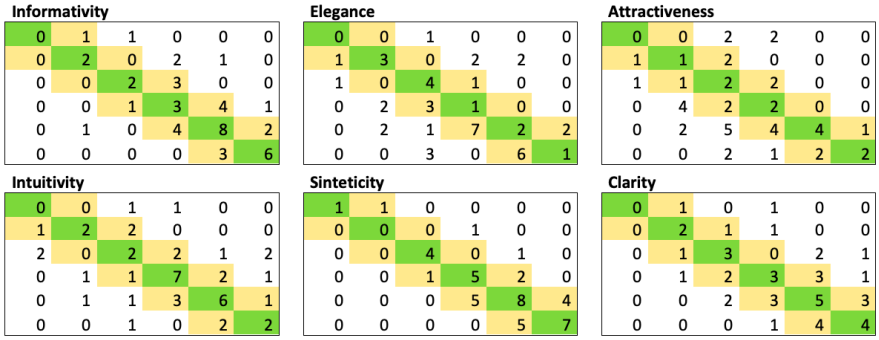

Fig. 5 Information quality dimensions. The number of participants who selected the same couple of answers: the column represents the animated infographic score while the row represents the aesthetic infographic score

Figure 5 presents every dimension as a table where each cell represents the number of participants who selected the same pair of values to answer the same question for both the infographics. The selected score is represented by the number of the column for the animated infographic and the number of the row for the aesthetic infographic. To better explain with an example, taking the first table in Figure 5, and considering the value in column 4 and row 2 (that is 2), this can be read as: two users assigned the score 4 (#column) to the animated infographic and the score 2 (#row) to the aesthetic one. Interesting is to notice that the cells in the diagonal (the green cells in Figure 5) represent the number of users who assigned the same score to both the infographics, while the cells in its immediate proximity (the yellow cells in Figure 5) represent the number of users who assigned similar value (with a difference of +1 or -1) to the two infographics. As an example, considering the second table (i.e., Elegance), the cell in column 4 and row 5 is telling us that 7 users selected the value 4 (somewhat agree) for the animated infographic and the value 5 (agree) to the aesthetic infographic. An interesting result to highlight is that, for each question, the number of users in the diagonal (i.e., the number of users who selected the same score for both the infographics) and

in its immediate proximity (i.e., the number of users who assigned similar score to both the infographics) represents the majority of users. In other words, the majority of the users didn't find any difference or just a little difference (+/- 1) comparing the two infographics, considering a specific information quality issue. To better see this result with the data, the number of users considering the yellow plus the green cells represents: informativity, 87%; elegance, 69%; attractiveness, 58%; intuitivity, 73%; sinteticity, 96%; clarity, 78%.

To have a complete overview of the relevance of all the dimensions per infographics, we computed the median value for each dimension and we plotted these data on a radar chart. The outcome is depicted in Figure 6 were it is well visible how the elegance and attractiveness dimensions are impacting more the aesthetic infographic, while clarity seems better describing the animated infographic.

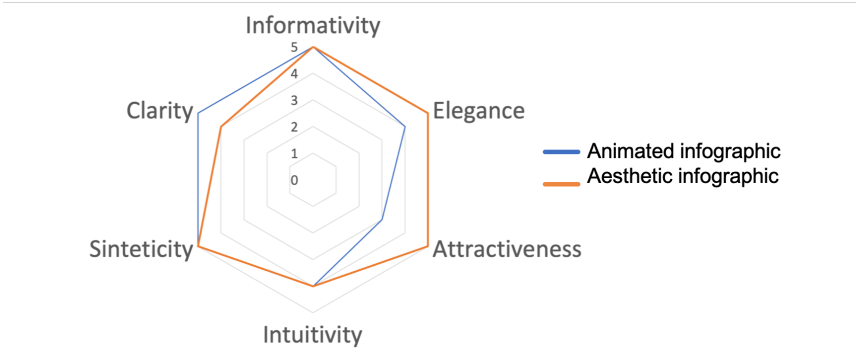

Fig. 6 Information quality dimensions. The median values obtained by the two infographics

Moreover, considering the different backgrounds and age of the involved participants, and their role within the University community, we decided to divide the collected results considering students (undergraduate, graduate, Ph.D.), and non-students (faculty and staff members). The outcome, considering the median value is presented in Figure 7. Interesting is to notice that for the intuitivity and sintenticity issues, the median values are exactly the same for all the groups, while for the other dimensions, it doesn't seem emerging a common trend. Considering the elegance and attractiveness dimensions, non-students seems to provide more distant score than students, while comparing the two infographics. Surprisingly, when focusing on informativity, it is possible to notice that students agree on the same score for both the infographics and, in the same way, non-students.

6.2 Design quality issues analysis

To analyzed the design quality issues, we exploited the same statistical analysis and visualization presented for the other dimensions. In particular, Figure

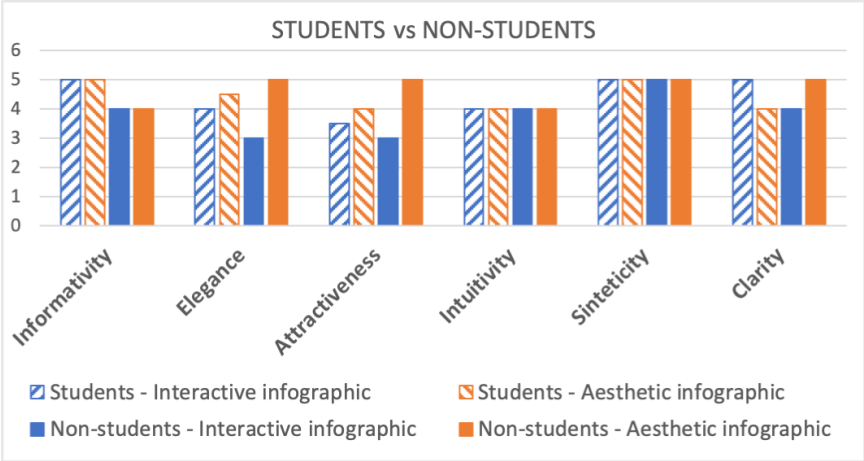

Fig. 7 Information quality dimensions. The median values obtained by the two infographics, grouped by students and non-students

Table 1 Questions and related design quality issues

Questions	Design quality issues
1	Essentiality - Redundancy
2	Abstraction - Abstraction
3	Functionality - Decoration
4	Density - Lightness
5	Originality - Familiarity
6	Multidimensionality - Monodimensionality

8 presents the distribution of the selected value (from 1 to 9) for each question regarding the animated infographic. Conversely, Figure 9 presents the same chart but using the data related to the aesthetic infographic. As already mentioned in Section 5.1, each question is defined with two opposite issues, so, for example, the first question (Question 1) goes from 1 (Essentiality) to 9 (Redundancy). All the questions and the related design quality issues are briefly presented in Table 1.

For each question, the order bars are colored based on the selected score (as defined in the legend). In these two charts, we grouped the number of participants who selected the same value, considering each question.

The outcome shows that the users seems perceiving the animated infographic more dense (56% of users selected a value from 1 to 4 in question 4) than the aesthetic one that is considered more light (49% of users selected a value from 6 to 9 answering to the same question); conversely, the aesthetic infographic is considered more original (values from 1 to 4 in question 5) by 71% of respondents (vs 44% for the animated one), and more essential (78% vs 60%, question 1).

To better understand the outcome, we computed the median values for these issues and plotted such values in the radar charts depicted in Figure

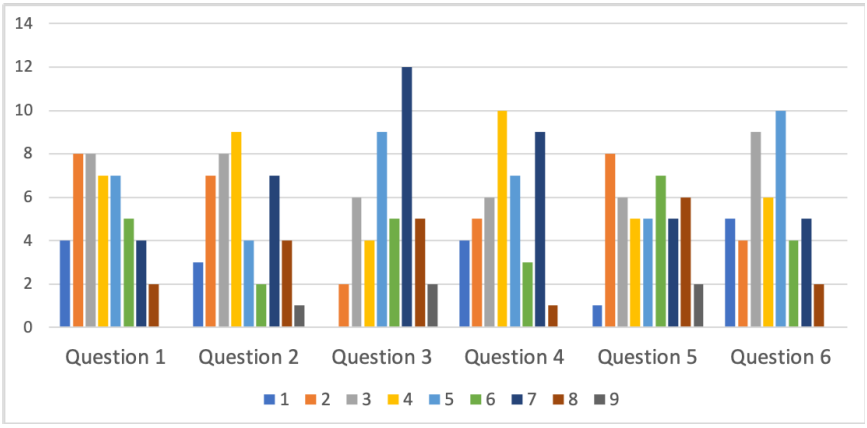

Fig. 8 Design quality issues. The distribution of the respondents' value (from 1 to 9): animated infographic

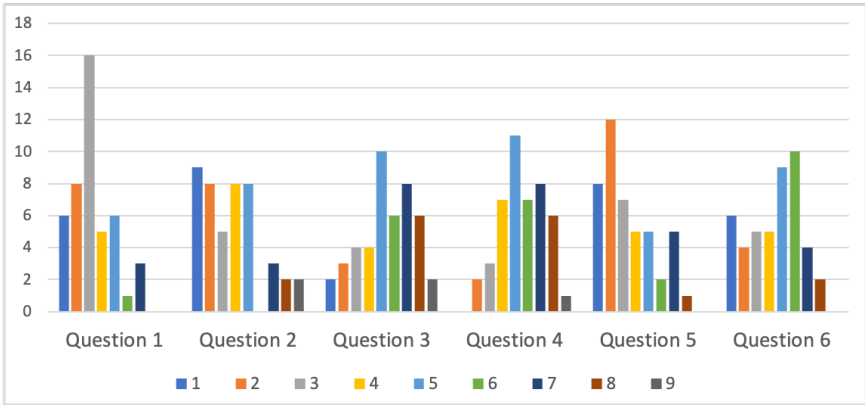

Fig. 9 Design quality issues. The distribution of the respondents' value (from 1 to 9): aesthetic infographic

10. To add more details, the visualized median values are calculated using a dataset created considering two values for every single question. In other words, in the radar chart, the two issues that are visualized in opposite position are the two issues concerning the same question (es. question 1 - Essentiality and Redundancy) and we calculated the two values as one the opposite of the other in a scale from 1 to 9 (for example, if the user selected 2, it means that the infographic is perceived strongly essential - value 8, than Redundancy - value 2). It is the same as having two distinct questions, both from 1 to 9, but negatively correlated.

Analyzing the radar char in Figure 10 at the top, we can claim that the issues that better describe the animated infographic, in contrast with the aesthetic one, are: multidimensionality, and lightness. On the contrary, the aesthetic infographic seems better described by originality and essentiality.

As we did for the infographic quality dimensions, we grouped the gathered data considering students and non-students; the outcome is presented is Figure 10, at the bottom. It is interesting to notice that, for the students, the shape of the radar chart is very similar to the one considering all respondents, on the contrary, the chart grouping the answers of non-students is different. Besides that, it is possible to see that essentially and originality remains the design qualities that better describe the aesthetic infographic. Focusing on the non-students values, it emerges as relevant a new interesting dimension for the animated infographic: functionality.

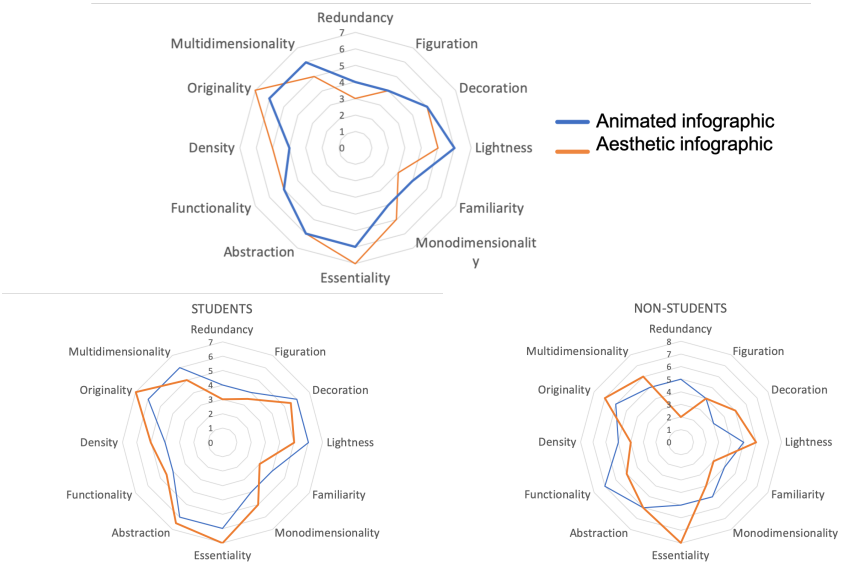

Fig. 10 Design quality issues. The median values obtained by the two infographics, grouped by all (on the top), students and non-students (on the bottom)

6.3 Awareness-related issues analysis

We recall that in the questionnaire we included two open questions for each infographic where we asked users to compute a task. The task was related to look for a piece of information relevant in the infographics (either animated or aesthetic) and to report it correctly. No significant differences were reported considering the two infographics. In fact, almost all the users answered in the right way considering the four questions (with the percentage of correct answers varying from 88% to 93%).

Moreover, we concluded the questionnaire asking if the user was feeling more aware of environmental issues after having interacted with the infographics (to be answered by selecting a value on a 5-points ordinal Likert-scale). The

majority of participants answered in a positive way: 22 (49%) agree and 17 (38%) strongly agree, out of 45 respondents.

6.4 Discussion and limitations

One of the main goals of this study was to evaluate two interactive infographics in order to find if a significant correlation exists between the users' perceived qualities and dimensions, and the implemented design. To this end, we designed two interactive infographics (i.e., animated and aesthetic) and we evaluated them using as a framework the model presented in [32]. The evaluation outcome highlights interesting results. First of all, it is possible to claim that both the interface obtained high scores when considering the information quality dimensions, validating our design decisions. Adding more details, the animated infographic was perceived more clear (clarity dimension) than the aesthetic one, conversely, the aesthetic infographic was perceived more elegant (elegance dimension) and attractive (attractiveness dimension). Regarding the design quality issues, we can maintain that the issues that better describe the animated infographic are multidimensionality, and lightness, while the aesthetic infographic seems better described by originality and essentiality.

Since we engaged the University community, we decided to analyze the collected data grouping them based on students and non-students. Interesting results and some differences seem emerging. For examples, for the design quality issue, focusing on the non-students values and the animated infographic, it comes into play the functionality dimension, not really interesting when considering all the data. Instead, considering the information quality dimensions, non-students seems providing more distant score than students, while comparing the elegance and attractiveness dimensions for the two infographics.

These preliminary results echo the outcome obtained by [32] confirming the fact that differences exist in the way groups with different characteristics perceived infographics. Moreover, with this case study we provide exploratory evidences regarding the possibility to use interactive infographics as a tool to foster awareness about environmental issues in a University community.

This study comes with limitations, which in turn pose some important avenues for future research. First of all, to provide significant pieces of evidence the sample of users involved in the study should be enlarge and more variegated in terms of background and ages. This is particularly true considering the non-student members that in this study represented only the 24% (11 out of 45). Enlarging the dataset will also allow performing other analysis considering more than one dimensions (gender, background, and so on). Another limitation of our study is related to measuring the perceived increase of awareness about environmental issues, including the post-usage retention of information. In this study, we asked users to interact with the infographics just for the time to find the content to answer the task. A more comprehensive study should be performed focusing on measuring awareness.

7 Conclusions and Future Work

The paper presents a system to visualize information related to the effort protracted over the last years by the University of Bologna for addressing the SDGs, and, among other things, towards a more sustainable use of forests, reducing the waste of paper. In particular, the focus of the paper is to present the design and the evaluation of two interactive infographics employing different graphical styles and navigation mechanisms. To evaluate the infographics, 45 members of the University of Bologna as been involved in answering an online questionnaire. Results, analyzed using statistical measures, shows interesting correlations between the data analyzed, the two infographics, and the different target audience involved (i.e., students vs faculty/staff members). Moreover, the majority of users answered in a very positive way (agree plus strongly agree) to the question related to the awareness gained about sustainability initiatives thanks to the interaction with the two infographics, confirming our approach. As future work, this issue related to awareness should be better investigated, giving the possibility to users to interact with one of the two infographics for a longer period, and comparing the results.

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